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DIVISION OF WATERSHED MANAGEMENT RESEARCH

Semiannual Report

U. S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

April - September 1958

SEMIANNUAL REPORT
Division of Watershed Management Research
April - September 1958

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SEMIANNUAL REPORT
Division of Watershed Management Research
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Washington Office

The study tour on watershed management, mentioned in the last semiannual report, continues to build up steam. Warren Murphy, Director, Division of Flood Prevention and River Basin Programs, has been named Co-Director of the tour and will work directly with the FAO in developing the project. A project manager is being provided from the Soil Conservation Service. Storey and Holscher are helping with their advice. The tour is tentatively planned for September-October 1959, and it is expected that the program will be completed by the end of the year. Detailed planning will then begin and some of you will be called upon to assist in this phase. About 30 participants are expected to attend, mainly from countries of the Far East, Middle and Near East, and Latin America.

The tour is expected to last two months, of which 6 weeks will be in the field. Stops will include certain selected research projects as well as action projects by the FS, BLM, SCS, and other Federal and State agencies.

As a part of the overall program of the U. S. Government in the disposal of surplus agricultural products, Public Law 480 was amended in the 85th Congress to include the use of foreign currencies, derived from the sale of surplus products, for agricultural research in foreign countries. Forest research is included. In F. Y. 1959, forest research will be done in seven countries with good prospects for continuation and expansion of the program. Countries included this year are Chile, Finland, India, Israel, Pakistan, Poland and Yugoslavia. (Watershed research is planned for Finland and Yugoslavia.)

The research must be of a kind that will be beneficial to both the recipient country and the United States and where special conditions--available scientists, institutions or site--make such research more feasible than if done in the United States. This work will undoubtedly extend our knowledge of soil-plant-water relations.

The pilot area soils program is progressing according to plan. Pilot areas are now being planned or worked on in all Regions except Alaska. Five areas will probably be carried through the area planning stage this winter. Field men in the 9 Regions now number 17. Reports are now being prepared for publication in the Department's Soil Survey Series for three areas. (The background of this program appears in the Chief's mimeographed circular memo of October 2.)

The Southeastern and Southern Stations brought together 30-40 of their people in the last week of October for a meeting to consider methods and techniques of measuring understory vegetation. The Research Divisions of Forest Management, Range Management, Watershed Management, and Forest Fire, and the Forest Survey were represented from the field and the W.O. was represented by Parker (Range Management Research), Harris (Range Management), Morey (Flood Prevention and River Basin Programs), Osborne (Statistical

Analyst), and Holscher (Watershed Management Research). A review was made of methods and techniques which have been developed and used to date, and evaluations were made by working committees of the usefulness of each method for southern and southeastern conditions. Certain aspects of overstory cover were also discussed with respect to their influence on cover and composition of understory vegetation, interception of precipitation, and evapotranspiration. Knowledge of accurate methods of estimating cover suitable for a variety of purposes will undoubtedly become increasingly important in interpreting watershed treatment effects and cover conditions.

Among the papers presented was "General Review of Methodology on The Use of Plant Cover and Composition for Measuring and Describing Forest and Range Vegetation" by Clark E. Holscher.

Forest Research Advisory Committee

Watershed management recommendations made at its Asheville meeting in September gave top priority to proposals for basic studies of hydrologic and erosional processes, protection of watersheds while subject to utilization, and water yield improvement. A fourth proposal, avalanche control research, advanced for the first time, received low priority.

Meetings, Papers, and Activities

Storey, Frank, Retzer, and Holscher have published articles or presented papers at professional, scientific or popular meetings. Storey's paper at the annual meeting of the Pennsylvania Forestry Association dealt with "Watershed Management - What it is and What it Does." His paper before the SCSA annual meeting was entitled, "Effects of Forest on Runoff." He has also submitted a paper to the International Union For the Conservation of Nature and Natural Resources on "Control of Erosion by Vegetation in Local Areas." He also coauthored with Pierce and Lull the article in Forest Science "Influence of Land Use and Forest Condition on Soil Freezing and Snow Depth."

Frank spoke before the Missouri Forest Resource Conference on "Water - In the Woods or Over the Dam," and before the National Advisory Committee of the American Forest Products Industries on "Forests and Water." On request of the Swiss Forest Research Institute he has also submitted a paper on "Some Aspects of Watershed Management Research in the United States."

Retzer delivered a paper on the subject, "Soil - a Factor Affecting the Distribution and Growth of Native and Exotic Forest Vegetation" before the Forest Soils Conference at East Lansing, Michigan.

Holscher has contributed "Grassland Management in a Watershed Program" to an FAO Handbook on Watershed Management now in preparation. (Other WMR people are contributing chapters also.)

Field inspections (by Frank at RM, and Holscher at NE) and participation in Hydrologic Subcommittee, AGU, and other watershed or hydrologic organizations continue to occupy the time of Division personnel. Both Storey and Frank will be on the program at the forthcoming AAAS meeting scheduled for late December in Washington, D. C.

References

1. "Landslides and Engineering Practice." Highway Research Board Special Report 29. 1958. (NAS-NRC Pub. 544). Ed. by Edwin B. Eckel. 232 pp. illus. Part I covers definitions, economic and legal aspects, types and processes of mass movements, their recognition and identification, air photo interpretation, field and lab investigations. Part II deals with solutions: prevention, control, correction, stability analyses, design of control methods, trends. Illustrations are given of specific problems and their control.

2. "Determining corrective action for highway landslide problems." In Analysis of Landslides. Highway Research Board Bull. 49 - NRC Pub. 220. 1952. pp. 1-27 incl. Appendices pp. 14-27. Lists 10 fundamentals of analyzing causes of problems, and discusses methods of controlling unstable highway conditions. -- B.F.

SEMIANNUAL REPORT

Division of Watershed Management Research
California Forest and Range Experiment Station

April through September 1958

GENERAL

At the San Dimas Experimental Forest spring rainfall was negligible after April 8, but 0.79 inch fell in August and September. This brought the total for the 1957-58 hydrologic year up to 48.08 inches, the third highest during the 30-year period of record at Tanbark Flat, and only slightly below the 48.23 high in 1940-41. All major streamgaging stations on the experimental forest were still recording streamflow on September 30 for the first time in 14 years.

At Berkeley a 4-day conference on watershed calibration was held September 16-19. Participants were Walt Hopkins, Henry Anderson, Perc Rowe, Arnold Court, Ray Rice, Clark Gleason, Bill O'Regan, the Station's Research Analyst and Ted Osborne from the Washington Office. Background hydrology, review of literature, current problems and model formulation all got beaten around. Nothing was sacred, except the right of free speech. We started on "Cloud 8" hoping to improve our approaches and procedures and develop better prediction equations. But we were still on "Cloud 5" at the end of the conference.

V. L. Harper visited the Station in June to inspect current research. He spent one day at San Dimas and another at the Snow Lab.

Contributions to the Colman Watershed Fellowship Fund now total approximately $31,000.

PERSONNEL

Everett L. Hamilton retired on April 30 after 41 years of government service, 25 of them at the San Dimas Experimental Forest in Glendora. Hamilton is now acting as a scientific consultant for the Forest and Watershed Conservation program of the Charles Lathrop Pack Foundation at Tucson, Arizona.

Jesse D. (Don) Sinclair, who has been at the San Dimas Experimental Forest for the past 25 years will be transferred to the Station headquarters in Berkeley. In his new position there he will serve as technical assistant to the Chief of the Division of Watershed Management.

Jay R. Bentley, formerly in Berkeley, is the new Research Center Leader at Glendora. He will continue as leader of the Fuel-Break program in California.

Two new Watershed Management men joined the staff at Glendora this last summer--Robert P. Crouse from Yale University, and Jay S. Krammes, a recent graduate of the University of Montana. Krammes has returned to Montana on educational furlough for his Masters degree, and will take over his duties as a full-time researcher next summer.

Frank Spalenka has been detailed to the San Dimas Experimental Forest from the Angeles National Forest for 60 days to aid in the water yield studies.

Two more trainees of the California Division of Forestry were assigned to work on the Big Dalton water yield study. Dave Johnson from the Fresno office spent a month on the experimental forest, and Richard LeBel from Monterey spent 2 weeks.

Ken Walsh left the snow research program to work for the Signal Corps at White Sands New Mexico.

PUBLICATIONS

Manuscripts Published

Andrews, Lowell A.
Reversal indicator for a water level recorder. Engineering News-Record, June 19, 1958.

Describes an attachment for indicating pen reversals on FW-1 water level records to aid in correct interpretation of streamflow records.

Helmers, Henry, and Ashby, William C.
Growth of native and exotic plants under controlled temperatures and in the San Gabriel Mountains California. Ecology 39(3): 416-428, July, 1958.

Describes a study to determine the species most adapted for survival and growth in the San Gabriel Mountains.

Manuscripts Accepted for Publication

Anderson, Henry W.
Progress in snow management research in California. To be published in 26th Annual Western Snow Conference Proc.

Plans, methods, and forest results from 18 studies now underway in California are summarized.

Anderson, Henry W.
Progress report, 1957-58 cooperative snow management research. Calif. Forest and Range Expt. Sta. 56 pp. illus., processed. June 30, 1958.

Objectives, methods, plans, and results of 18 snow management studies are summarized, together with basic meteorological, snow, and streamflow measurements.

Anderson, H. W., Coleman, G. B. and Zinke, P. J.
Summer slides and winter scour--dry-wet erosion in southern California mountains. Tech. Paper 144, 9 pp., 1958.

Summarizes the results of 4-years of study of sources and process of soil, rock, and organic debris movement down San Gabriel slopes.

Anderson, Henry W., Rice, Raymond and West, Alan
Forest shade related to snow accumulation. To be published in 26th Annual Western Snow Conference Proc.

Electronic computer was used to test various measures of forests as they affect snow accumulation. The measures tested ranged from a single-valued index of forest cover (cover density) to 7-variable expression of the same forest cover. The evidence was that forest variables were improved when we specifically designed them to index the separate effects of forests on solar radiation received at the snow surface, back radiation from the trees, and interchange of energy between forests, clouds and sky. Many of the forest effects are not linear; forest effects are much better indexed when this is taken into account in the analysis.

Court, Arnold
Selection of best snow course points. To be published in 26th Annual Western Snow Conference Proc.

The median snow water equivalent of 5 points was found to be practically as good a measure of snow at snow course as is the mean of 17 points, both in estimating the "true" mean of the course and for predicting the flow of a nearby stream.

Hopkins, Walt
Cooperative financing of water management projects in California. To be published in Proceedings of Second Annual Meeting, Arizona Watershed Program.

A discussion of State and Federal cooperative water management and watershed management research projects in California.

Hopkins, Walt, Sinclair, J. D. and Rowe, P. B.
From forest influences to applied watershed management in southern California. To be published in Proceedings, 1958 Annual Meeting Soc. Amer. Foresters.

A review of past research accomplishments at San Dimas and a discussion of present pilot plant water yield studies underway.

Rice, Raymond M.
Snow management research in high sierra range. Submitted to the Jour. of Range Management.

A range management point of view regarding snow management research in California.

Rowe, P. B.
Tests of applied watershed management to increase water yield--San Dimas Experimental Forest. To be published in Proceedings of Second Annual Meeting, Arizona Watershed Program.

A review of the major pilot plant water yield study underway at San Dimas in Monroe and Bell Canyons.

CURRENT RESEARCH

San Dimas Experimental Forest

Watershed Management Tests to Increase Water Yield

We continued field work on modifying the vegetative cover to increase water yield in Big Dalton Canyon. In one of the two applied watershed management tests in this drainage, a fuelwood contractor and labor crews cleared the trees and shrubs from 15 acres of the woodland-riparian zone in Monroe Canyon before work was stopped June 1 because of the high fire hazard. Logs, slash, and other floatable debris were removed from the stream channel to avoid bulk flows during storms. Stumps were sprayed with a 2, 4-D and 2, 4, 5-T mixture as the trees were cut. Later, the sprouting shrubs and the forbs were sprayed by hand. In the other test, 40 acres of brush on those side slopes on deeper soils in 100-acre Bell watershed No. 2 were sprayed by helicopter in April.

We plan to treat the woodland-riparian vegetation in an additional 65 acres of the 875-acre Monroe Canyon watershed during the coming winter. The 40 acres of chaparral side slopes on deep soils in the Bell watershed will be phytocide sprayed again next spring.

Good progress was made in developing equipment and in planning the supplementary studies needed to evaluate changes in total water production from the treated watersheds. The neutron probe, according to Bob Merriam, has proved reliable for measuring soil moisture content. Measurements made with the probe, Colman electrical resistance units, and gravimetric sampling in the homogeneous lysimeter soil showed almost identical total water contents in 6 feet of soil.

Jim Patric is working on a device for direct measurement of transpiration losses.

Grass Interception Study

Bob Crouse is making a plan for study of water loss through interception of rainfall by native grass. Information from this study will plug the gaps in our knowledge of how interception by grass at different growth stages affects water yield. The study, to be started this winter, is made possible by new cooperative funds from the California Division of Forestry.

Snow Studies

Forest Relations to Snow Accumulation

Increments and depletion of the snow pack over 1-5 weeks period at Central Sierra Snow Laboratory snow measurement points were related to single and multi-variable indexes of the forest in some recent analyses. Climatic controls were included to index the gross differences in amount of snowfall, solar energy, and wind between periods. Climatic controls were of two kinds, (1) snow course data at a course relatively free of forest effects, and (2) meteorological measurements - solar energy, clouds, and wind. The forest cover variables were selected to index specific variations they brought about in each climatic effect at each snow measurement point.

The forest variables were aimed at indexing the forest effects on snow reaching the ground, redistribution of snow, and melt. Interception of direct solar radiation by the forest canopy was indexed by the cover density and depth. To obtain one index the cover density in the solar path during a period of snow increment was weighted by the energy received each hour of the day in that path. Tabulations of solar intensity received on any slope, made by our Fire Research Division, facilitated these weightings. To index the effects of multiple reflections within the canopy in retarding penetration, we used the depth of the canopy, again weighted by the solar energy for each hour in the solar path. Depth would be particularly important for the infra-red radiation, which is highly reflected by forest vegetation and so may bounce through thin vegetation which appears dense to ordinary visible light. What we see and what a camera sees is not what the snow sees.

To index the long-wave radiation balance between forests, snow, and sky we chose the hemispherical cover, weighted by the cover density. This is the proportion of the sky obscured by the trees. In addition, the interception of snow was indexed by the hemispherical cover times the amount of snowfall at the control snow course. It is obvious that hemispherical cover should also influence wind scour, melt, and evaporation. To index the net effects of wind, we used the "hemispherical cover" in the SW and NE octants, called the "Shelter", weighted by the total wind passage during the period. Analyses by Court have shown that most of the winds during snow storms and most of the warm afternoon winds between storms come from the southwest. The results are too lengthy to be given here A paper has been submitted to Western Snow Conf. for publication ("Forest shade related to snow accumulation".)

Effects of Logging on Hydrologic Processes

At the Onion Creek watersheds evaluation of the effects of logging on interception, snow accumulation, snow melt, and soil moisture losses, is being made. The effects of a "conventional logging show" on snow accumulation and melt are shown below:

Condition	Water Equivalent -- Inches					
	Jan. 17	Feb. 28	Apr. 25	May 6	May 27	June 20
Forest Uncut	10.0	27.5	51.2	43.5	24.6	1.7
Forest Cut	13.0	33.1	58.3	48.4	23.2	1.1
Difference	+3.0	+5.6	+7.1	+4.9	-1.4	-0.6

The differences are about as expected: more snow accumulation in the cut area, then more rapid spring melt.

Evaporation and Condensation from Snow

Two studies are underway on evaporation from snow: one is a part of Al West's winter evapo-transpiration studies at the Lab and one is near the Teakettle Experimental Forest under Clark Gleason's direction. Results for 1957-58 are shown.

Central Sierra Snow Laboratory Results

Evaporation from snow surfaces was slight at the Central Sierra Snow Laboratory. February to June loss in a small forest opening

(about half the height of the trees across) totaled 0.8 inches; loss under a forest canopy was 0.3 inches. The summary by months is shown below:

Month	Evaporation from snow--inches	
	Under Forest Canopy	In Small Opening
February	0.017	0.089
March	0.048	0.184
April	0.358	0.495
May	-0.036	0.108
June	-0.052	-0.030
Total	0.335	0.846

In the latter part of May measurements were taken three times per day. Evaporation occurred during the Noon until 4:00 p.m. period, then condensation took place during the period 4:00 p.m. to 8:00 a.m., and continued in the 8:00 a.m. to Noon period.

The effect of wind on evaporation and condensation at several parts of openings was studied. The part of a forest opening exposed to the wind (the north and west margins) had excess evaporation on days in which evaporation was general, and excess condensation on days when condensation was general. Other data have not yet been summarized.

Teakettle Experimental Forest Results

Condition	Median evaporation Inches per day	Estimated yearly Loss Inches
In forest	-.0098	-2.2
In small openings	-.0018	+0.2
In large open area	+.0104	+2.3

The difference of 4.5 inches loss between forest and large open area could be important in total water yield. On the other hand the heat from condensation of 2.2 inches of vapor in the forest could melt 15 inches of snow water equivalent, partly offsetting the effects of shade of the forest in reducing melt.

Swain Mountain Experimental Forest Snow Studies

Snow accumulation and melt in red-fir stands of various densities and in forest openings were measured last winter. The results are summarized in table 1.

Table 1.--Swain Mountain snow studies--average water content

FOREST	POINTS	1958 DATE 1/6-7	2/6-7	3/4-5	4/9-10	5/1-2	6/4-5
		Inches					
Very dense Red Fir	A 1-15	5.4	14.6	20.8	35.6	30.3	4.5
Opening 1-1/2 H	A 16-21	8.3	22.5	30.8	47.4	39.6	3.9
Very dense Red Fir	A 22-33 & 58-65	4.9	15.2	20.5	33.2	28.8	2.2
Dense Red Fir	A 34-57	5.6	15.1	20.8	34.9	29.3	4.0
Small Openings	C 1,2,9,24 & 34	8.3	24.9	30.8	-	41.5	14.9
Open Old Red Fir	C All other	7.4	21.3	28.4	-	38.4	8.3
Old-Young Red Fir	D All D	6.7	19.7	29.0	-	40.1	11.2
Opening	Swain Mt. Course #2	7.1	20.3	26.2	45.8	32.5	No snow

The snow is being measured prior to strip cutting of Block A and unit-area control block cutting in blocks C and D. The cutting is being done by the Forest Management Division as part of their research.

Erodibility of California Wildland Soils

This summer Johnnie Andre' started sampling soils of major geologic, vegetation, topographic and geographic zones of California's wildlands. He took 177 samples in all. Soil erodibility will be related to sediment production from 75 watersheds of northern and central California. The method is statistical, relating measured sediment deposition and suspended sediment measurements from whole watersheds to soil erodibility, the watershed characteristics and the climatic causes of sedimentation.

Tools and Techniques at the Snow Lab

Nuclear soil moisture measurements

The Nuclear Chicago P19 probe and 2800 scaler are making possible measurements of soil moisture in stony forest soils. We carry the probe bare on a 6-foot pole between sampling spots.

Two probes are now in operation. Comparison between the two probes in the same soil profile gave essentially identical readings--within 1 percent soil moisture. They have been used effectively on a 7-day per-week basis for more than 3 months. We have had some minor difficulty with "spurious counts" attributable variously to a faulty vibrator, excess heating of scaler in direct sun, and loose connections. We have had no trouble in the last month. One probe was repaired at the factory. The service given was highly satisfactory.

Photocanopymeter

Ashton Codd of the Soil Conservation Service in Bozeman, Montana has come up with an excellent way of permanently recording canopy density. A pinhole camera is used. We have adapted the idea so that we get a picture of 156° of the hemisphere on a 4 x 5 photo negative. A plate holder set 1/2-inch from a pinhole .015 inches in diameter held in an improvised box is mounted on a tripod. A simple cap serves as a shutter to give time exposures of 5 to 15 seconds. We will furnish specifications to anyone who wants them.

Dirt cheap radiometer

We all want a radiometer that will integrate radiation received, be inexpensive, and not require laborious chart interpretation. Cliff Mansfield is working on an idea growing from contacts with the National Bureau of Standards and Bert Goodell. It involves a system in which heat absorbed by a plate is converted by thermocouples to electrical energy which is stored by a capacitor. The rate of

charging the capacitor is a measure of the heat absorbed. The discharge from the capacitor, amplified by transistors, operates a relay counter which tallies the radiation. Looks hopeful; costs less than $20.00. Still not field tested.

De-icing of anemometer

We have tried to prevent anemometers and wind vanes on Mt. Lincoln from icing up during snow storms. A special silicon anti-icing compound (General Electric) delayed icing somewhat, but the anemometer still iced up. Black paint on the anemometer was even less effective. Correspondence with the Mt. Washington people and others indicate the only solution is "a small boy with a stick continuously knocking the ice off"--no small boys--no wind measurements on Mt. Lincoln.

MEETINGS

April 5-8.--At the Amer. Geophys. Union Meeting in Washington D. C. Robert Hobba presented a paper jointly authored with Henry Anderson. The title was "Forest effects on floods in the Pacific Northwest".

April 8.--The State of California, Soil Conservation Commission, State and Area heads of the Soil Conservation Service and other key soil conservation leaders making up a group of about 50, made San Dimas the first leg of a 2-day, southern California meeting.

April 16-18.--Henry Anderson, Ray Rice, and Arnold Court presented papers at the Western Snow Conference at Bozeman, Montana. The papers were "Forest shade related to snow accumulation" by Henry Anderson, Ray Rice and Al West, "Progress in snow management research in California" by Henry Anderson, and "Selection of best snow course points" by Arnold Court.

April 19.--The research program and results at the San Dimas Experimental Forest were presented to the University of California School of Forestry faculty and California Station Division Chiefs.

May 7.--Hopkins met at the combined meeting of the California Board of Forestry and the Los Angeles County Watershed Commission and formally presented the San Dimas research program.

May 16.--Sinclair talked to the senior class at Citrus High School on "the conservation of natural resources".

May 22.--At a joint hearing of the State Senate Interim Committees on"Forest Practices and Economic Redevelopment of Cutover Timber Areas and Brushland"in Sonora, Hopkins presented a statement and was interrogated on San Dimas and North Fork brush conversion research results.

June 11.--The California Board of Forestry, along with several of their wives, met at the Snow Lab for a review of the Snow Research Program.

June 17-19.--Arnold Court and Henry Anderson presented papers at the section on Meteorology of the AAAS in Logan, Utah. Court also read a paper by Everett Hamilton. The papers were titled "Decrease in lightning-caused forest fires through cloud seeding" by Court; "Rain-snow flood sources meteorologically defined" by Anderson, and "Improved determination of rainfall rates in mountain watersheds" by Everett Hamilton.

July 17-18.--The Annual San Dimas Advisory Committee Meeting was held at Tanbark. The program dwelled largely on a review of the Big Dalton water yield study. Bentley and Chandler made short presentations of Fuel-Break and southern California fire research.

August 5-8.--The Natural Resources Committee of the California Farm Bureau Federation made a 4-day tour of Station activities, spending one day at San Dimas and another at the Snow Lab.

August 11.--Merriam presented "the research program on the San Dimas Experimental Forest" to the San Dimas Kiwanis Club.

September 22.--Rowe presented a paper on "Tests of applied watershed management to increase water yield" and Hoover read Hopkins' paper "Cooperative financing of water management projects in California" at the second annual meeting of the Arizona Watershed Program in Phoenix, Arizona.

September 29-30.--Hopkins and Anderson presented papers at the Soc. Amer. Foresters Meeting in Salt Lake. The papers were titled:"From forest influences to applied watershed management in southern California" by Hopkins, Sinclair, and Rowe, and "Snow in forest openings and forest stands" by Anderson, Rice and West.

COOPERATION

Hopkins, Rowe and Sinclair met with the directors of the Vista Irrigation District in San Diego to discuss riparian vegetation water use along the San Luis Rey River.

Merriam and Patric assisted Dr. Robert Colwell, Professor of Forestry at the University of California, and Mr. Sintzenich, photographer for the Pan American Institute of Geography and History, in planning and photographing scenes for possible inclusion in a training film on use of aerial photographs in making a water inventory in undeveloped regions.

VISITORS

The San Dimas Experimental Forest was visited by 182 persons during the 6-month period. Included were 35 college students and 14 foreign visitors.

SEMIANNUAL REPORT

DIVISION OF WATERSHED MANAGEMENT RESEARCH

CENTRAL STATES FOREST EXPERIMENT STATION

April 1, 1958 - September 30, 1958

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SEMIANNUAL REPORT

DIVISION OF WATERSHED MANAGEMENT RESEARCH

CENTRAL STATES FOREST EXPERIMENT STATION

April 1, 1958 - September 30, 1958

GENERAL

The limited research facilities at the Soil and Water Conservation Research Station - ARS, Coshocton, Ohio, prevent Forest Service staff members from being headquartered at Coshocton. Several technicians of the Watershed Technology Branch, ARS, are assembling and organizing data from earlier forest studies. ARS is transmitting the processed data to the Central States Station. Technicians in the Ohio Agricultural Experiment Station and Athens Research Center are helping to inventory forest stands. A program conference has been tentatively scheduled for the spring of 1959 to consider studies to be undertaken on the five forested watersheds.

After analyzing the watershed problems of the Central States area, we decided to develop a strong research program in Ohio. High priority is given to basic studies of regional scope. Headquarters for the team of watershed researchers is in Columbus, Ohio. Lawrence W. Hill reported for work in June. Ronald Z. Whipkey transferred from the Columbia Research Center to the New Philadelphia Field Office on August 27. Richard B. Marston transferred from the Intermountain Station to Columbus on September 1. This gives four technical personnel and our organization is as follows:

Columbus, Ohio:-

E. A. Johnson, Division Chief
R. B. Marston, Project Leader, Watershed Management Research in Ohio
L. W. Hill
Mrs. Stella A. Townsend, Secretary

Athens (Ohio) Research Center - New Philadelphia Field Office:-

R. Z. Whipkey

Training - thesis projects

Hill, Marston, and Whipkey were engaged in thesis projects during the last six months. Their theses are:

Hill - Precipitation and runoff relationships on a reforested watershed in Ohio. University of Michigan.

Marston - Disposition of precipitation on some aspen and mountain brush sites in Northern Utah. Utah State University.

Whipkey - Some basic precipitation and runoff relationships for three small watersheds in the Missouri Ozarks. University of Missouri.

A fourth thesis was a cooperative aid project with the Soils Department, University of Missouri. George Carter's thesis "The determination of moisture in rocky soils" was completed in August.

OHIO

Athens

Carmean has placed major emphasis on analyzing data and preparing manuscripts for studies of litter and soil moisture. Two manuscripts have been prepared and these are now being reviewed. Following are abstracts from these manuscripts:

Effects of converting ridge sites to pine on the Vinton Furnace Experimental Forest

A. Litter

"Clearcutting poor-site oak stands does not reduce litter weight" by Willard H. Carmean.

Clearcutting has not reduced the weight of litter in poor-site upland oak stands in southeastern Ohio. Four years after a conversion study was established by clearcutting hardwoods and planting pines there is as much litter in clearcut areas as in nearby stands of uncut oak forest. Samples of L, F, and H layers were collected in September of 1954, 1955 and 1957 on 6 clearcut and 3 uncut plots using a sharp-edged, 1 square foot metal frame. Average weight of L, F, and H layers on the uncut plots was 2,880, 6,070 and 17,720 pounds per acre, respectively. Weights of L, F, and H layers found on clearcut plots were not significantly different from the weights of these layers found on uncut plots.

B. Soil moisture

"Soil moisture changes resulting from clearcutting poor-site stands in southeastern Ohio" by Willard H. Carmean.

Weekly gravimetric soil moisture measurements were made in uncut and clearcut oak forest in southeastern Ohio over a period of 19 months (1954-55) following clearcutting. The forest was

located on an upland ridge and was a well-stocked, poor-site, mature oak stand growing on a shallow, heavy-textured, slowly permeable soil.

Results of this investigation are as follows:

1. Soil-moisture measurements, during the first growing season following clearcutting, showed much more moisture in clearcut plots than in nearby plots of uncut oak. However, during the second growing season after cutting, moisture levels in the clearcut plots were much lower and approached those of uncut oak plots.

2. Differences in soil water depletion were found for the A, B, and C horizons. For equal volumes of soil, the A horizon contained more water and lost it at a faster rate than the underlying horizons. The tough, heavy-textured, plastic C horizon had the slowest rate of depletion. However, the B and C horizons lost the greatest amounts of soil moisture because they were much thicker than the A horizon. From May to early November of 1954 cumulative soil moisture depletion from uncut oak forest equaled 12.3 inches. Of this amount only 13 to 18 percent was lost from the thin A horizon; the remainder was lost from the B and C horizons.

3. Total evapo-transpiration from uncut oak forest, during the six months of June to November, 1954, was about 21.8 inches of water. Considerable variation of weekly evapo-transpiration rates was observed in response to season of year and to varying conditions of soil moisture and rainfall. Rates of evapo-transpiration as large as 0.28 and 0.31 inches of water per day were observed in August of 1954 and 1955 under circumstances of moist soil and abundant rainfall.

4. An estimation was made of rainfall losses due to deep seepage, subsurface flow, surface runoff, and losses due to interception by vegetation and litter. These estimates indicate that 39 to 50 percent of total rainfall fails to enter the soil profile. Most of this loss is thought to be due to interception by tree crowns, understory vegetation, and surface litter layers.

New Philadelphia

Whipkey transferred to a field office of the Athens Center -- the Muskingum Conservancy District Building at New Philadelphia, Ohio. Some of the future watershed research in Ohio is to be conducted in cooperation with the Muskingum Watershed Conservancy District. This organization is one of 23 watershed conservancy districts in Ohio, and has ownership of some 53,000 acres of land above its flood-control reservoirs.

Columbus

Effects of changing types of vegetation (grass to trees) on:
Growing season depletion curves

Watershed 172 is a 43.6 acre watershed at the Soil and Water Conservation Research Station, Coshocton, Ohio. Prior to installing the gaging station, two-thirds of the watershed had a stand of grass and brush and one-third had a stand of uneven-aged hardwoods. The non-forested area was planted in 1938 and 1939 primarily with white, red, and pitch pine. Two small areas were planted with black locust.

The period of record covered 18 years; from 6/1/39 to 5/31/57. Growing season - May 1-September 30.

Depletion curves were derived mathematically from mean daily flow tabulations by matching successive series of receding flows as described in SEFES Paper No. 68.

The period of record was divided into 3 periods; 6/1/39-5/31/45, 6/1/45-5/31/50, and 6/1/52-5/31/57, and depletion curves were calculated for each period. Data in Table 1 illustrate the time-discharge relationship between the periods.

Table 1. Time-discharge relationship between periods for the growing season, May 1-Sept. 30, Watershed 172, Coshocton, Ohio

Period	Age of Plantation	Days							
		1	5	10	15	20	23	26	30
	yrs.	csm	csm	csm	csm	csm	csm	csm	csm
1939-1945	0- 6	8.3	3.3	1.07	0.34	0.11	0.055	0.028	0.010
1945-1950	6-11	6.9	2.4	.62	.16	.04	.019	.010	-
1952-1957	13-18	8.0	2.4	.54	.13	.027	.010	-	-

A change in the ground water contribution to streamflow has occurred during the study period, and is very noticeable 5 days after storm precipitation. In the 1939-1945 interval it took 30 days for groundwater to deplete to .01 csm (.00037 area inches) per day.

For the 1945-1950 and 1952-1957 intervals it took 26 days and 23 days, respectively, for groundwater to deplete to the same level.

It is logical, therefore, to assume that the conversion of the watershed to complete forest cover has resulted in changing the time-discharge relationships. As the time was reduced for groundwater to reach the same rate of flow (.01 csm) the area inches of storage corresponding to a given rate of flow must also have been reduced. Table 2 illustrates these changes.

Table 2. Storage-discharge (gravitational water available for streamflow) relationships between periods for the growing season, May 1-Sept. 30, Watershed 172, Coshocton, Ohio

Period	Age of Plantation	Days								
		1	5	10	15	20	23	25	26	30
	yrs.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1939-1945	0- 6	1.52	.57	.19	.06	.02	.010	.0005	T	T
1945-1950	6-11	1.10	.38	.10	.03	.006	.003	T	T	T
1952-1957	13-18	1.16	.35	.08	.02	.004	.001	T	T	T

By using a base of .01 CSM common to all periods it is possible to determine the loss in area inches of water previously available for streamflow. This amounts to 0.36 inches. In other words, after a storm during the 1952-57 period, for the time it takes streamflow to reach 0.01 CSM, there is now 0.36 inches less runoff than in 1939-45.

Berea Research Center

Effect of type of vegetation and slope position upon soil moisture use

In a small exploratory study soil moisture was sampled in triplicate to a depth of 30 inches at weekly intervals throughout the summer of 1957 on the following four sites:

1. Broomsedge vegetation, lower slope,
2. Forest vegetation, lower slope,
3. Forest vegetation, middle slope,
4. Forest vegetation, upper slope.

Clay content of soil on the forested plots was lower and sand content was higher than on the broomsedge plot.

Bulk density was about the same for all depths on the broomsedge plot, but on the forested plots bulk density of the surface layer was 18-20 percent lower than at deeper levels. When values were averaged for the full 30 inch profile the bulk density of all plots varied only from 1.443 on the forested, middle slope plot to 1.492 on the forested, lower slope plot.

Variations in the soil characteristics resulted in a 12 percent difference between sites, in the amount of water the 30 inch soil mantle could hold.

Moisture content of the soil was high when sampling began near the end of April and all plots showed a marked depletion throughout the summer. It was interrupted by frequent summer rainstorms but was especially rapid from April 29 to May 6 and from June 10 to June 24 (Figure 1).

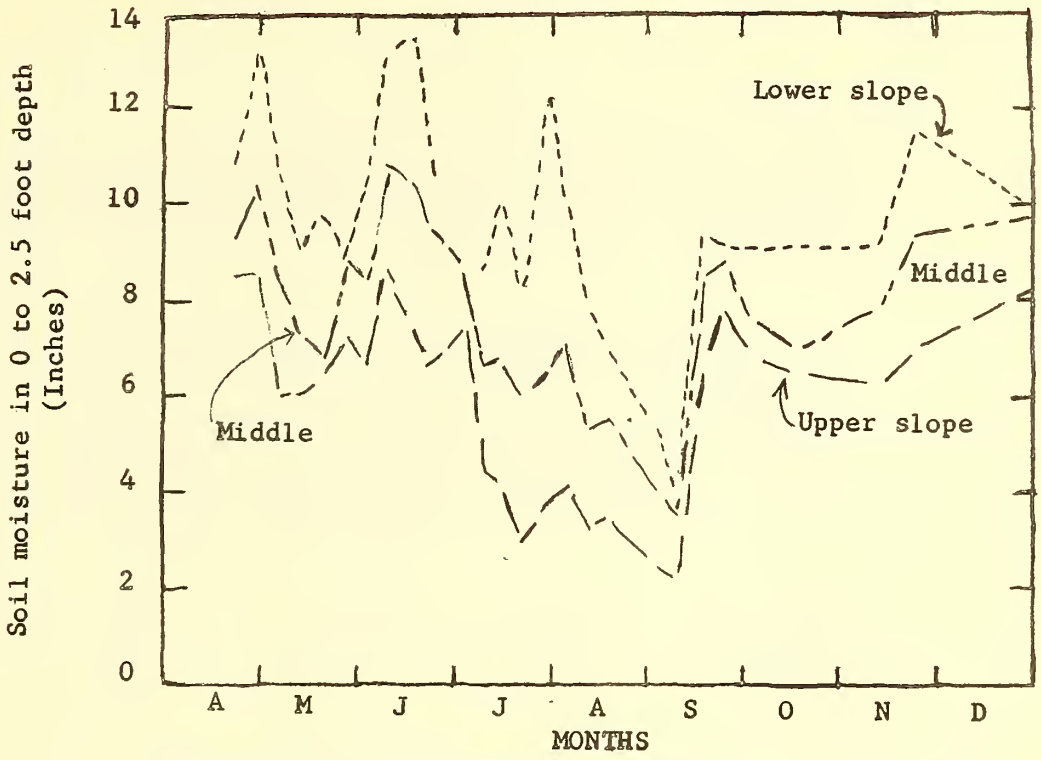

Figure 1. Soil moisture record at the 0 to 2.5 foot depth for forest vegetation on three slope positions, Berea College Forest, Kentucky.

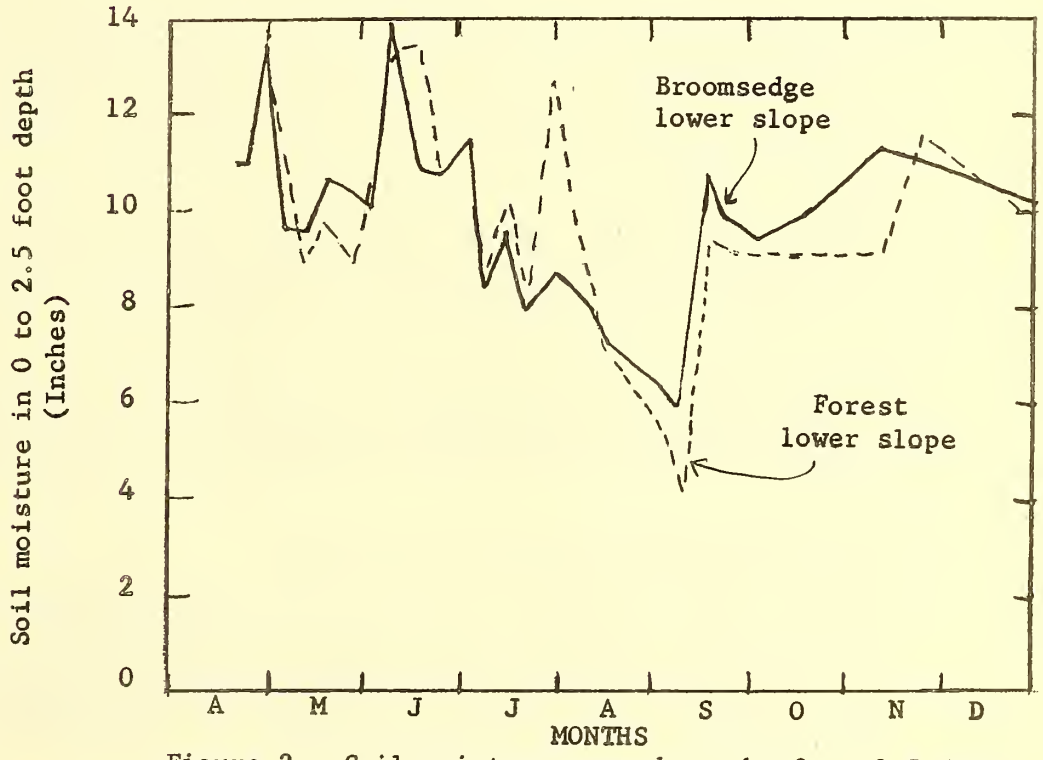

Figure 2. Soil moisture record at the 0 to 2.5 foot depth for forest vegetation and broomsedge on a lower slope in Berea College Forest, Kentucky.

Precipitation between April 29 and September 9 totaled 13.84 inches. Adding this to the difference between moisture contents on these two dates indicates a 20-23 inch E-T loss from the 30 inch soil mantle, Table 1.

Table 1. Water loss during selected periods as affected by type of vegetation and position on slope, Berea Forest Research Center, 1957

Period	Plots			
	Broomsedge	Forested		
	Lower slope	Lower slope	Middle slope	Upper slope
	Rate, inches per day			
4/29-5/6	.58	.36	.32	.36
6/10-6/24	.32	.30	.20	.24
7/8 -7/22	.08	.08	.08	.15
8/12-9/3	.11	.15	.09	.07
4/29-9/9	.16	.17	.16	.15
	Total, inches			
4/29-9/9	21.73	23.03	20.68	20.01

These losses from only the 30 inch mantle may be quite reliable for the broomsedge plot because most of the roots are concentrated in the upper 18 inches of soil and almost none of them go below 30. The losses from the forested slopes are most likely only indicative because many of the roots go below 30 inches. They do show that the rate of loss is rapid in the spring and after storms -- when much is available.

Later in the summer the loss rate decreases. In the case of broomsedge this may be because of cessation of growth but in the forest it may be because there is less water available in the upper layers and the trees are drawing it from lower depths.

Theoretically the loss from the forested slopes should have been greater than from the broomsedge. That this is not shown in Table 1 of this study is due, no doubt, to sampling only to 30 inches.

Columbia Research Center

Whipkey spent two weeks in June with Professor Fletcher of the University of Missouri surveying a 14 acre watershed and gage site on the School Forest, Butler County, Missouri. The general watershed area lies within the upper flood pool of Wappapello Dam and was obtained from the Corps of Engineers. Principal cover is

oak-hickory forest with scattered gum, yellow poplar and elm at the gage. The main channel is ephemeral, but two small "wet weather" springs just upstream from the gage may contribute some seepage during nonstorm periods. During maximum flood stages, the gaging station may be submerged. Fletcher expects this to be the first in a series of gaged forest watersheds at the School Forest.

Negotiations are underway for a cooperative aid project with the Department of Forestry, University of Missouri, to measure the amount of precipitation intercepted by hardwood forest litter in the open and under forest tree canopy. This study is to be undertaken in a 40-year old, pole-sized, scarlet oak stand on upland "flatwoods" on the University Forest, Butler County, Missouri. Professor Fletcher will be responsible for the project.

On August 1 Whipkey received a Master of Science degree from the University of Missouri. Major studies were in the field of hydrology and the thesis was based on precipitation-runoff relations of small watersheds in the Missouri Ozarks.

Cooperation - Soils Department, University of Missouri

George Carter graduated August 1. Carter's thesis was based on the cooperative aid study of rocky forest soils in the Missouri Ozarks.

MEETINGS AND TALKS

April-June — During Professor Fletcher's absence Whipkey lectured to the graduate class in Forest Influences at the University of Missouri.

May 14-15 — Johnson attended the Ohio Mid-Century Governor's Conference on National Resources. He presented a paper, "The Role of the Land on Ohio's Water Resources."

August 4-8 — Carmean attended the annual meeting of the Soil Science Society of America, held at Purdue University, Lafayette, Indiana.

Sept. 8-12 — Carmean attended the North American Forest Soils Conference held at Michigan State College, East Lansing, Michigan.

PUBLICATIONS

Manuscripts Published

Carmean, W. H. Silvical characteristics of yellow buckeye. Misc. Release 29.

New Manuscripts

Whipkey, R. Z. and Fletcher, P. W. Precipitation and runoff relationships for three small watersheds in the Missouri Ozarks. University of Missouri Agricultural Experiment Station Research Bulletin.

Whipkey, R. Z. Precipitation and water yield in the Ozarks. Journal of Soil and Water Conservation.

Carmean, W. H. Clearcutting poor-site oak stands does not reduce litter weight.

Carmean, W. H. Soil moisture drainages resulting from clearcutting poor-site oak stands in southeastern Ohio.

BOOK REVIEW

by: R. Z. Whipkey

Engineering Hydrology by Stanley S. Butler, Associate Professor of Civil Engineering, University of Southern California. Prentice-Hall, Inc., 1957. 356 pp., illus.

Engineering Hydrology is the first complete hydrology text since 1949 and is aimed at both professional engineers and water specialists. Since World War II the trend in hydrologic research has been to emphasize the quantitative rather than the qualitative approach. The author has attempted to present both the older "tried and true" procedures along with some of the newer analytical methods developed since 1949. Three chapters are devoted to precipitation and analysis of data, four chapters to infiltration, sub-surface water and ground water hydraulics, and four chapters to streamflow, floods, and analysis of these data. The subject matter is covered in a very concise (often sketchy) manner and the book, by itself, could hardly be considered a "first reader" in hydrology. However, 30 to 70 representative problems are included at the end of each chapter, and when used with one of the older texts (Wisler & Brater, Linsley et al, etc.) this book could be a valuable training reference.

SEMIANNUAL REPORT ON WATERSHED MANAGEMENT RESEARCH
Intermountain Forest and Range Experiment Station
April - September 1958

GENERAL

Following unusually deep snowpacks at the higher elevations last winter, the summer provided contrastingly low rainfall. Only scattered showers punctuated the period from May until October.

The Station and the Davis County experimental watershed had the usual large number of visitors from over the United States and foreign countries. Among foreign countries represented were Germany, southern Rhodesia, Greece, Turkey, Spain, and Japan. A highlight was the visit of Herr Walter Mann, Ministerialdirektor of the German Forest Service, Mr. Wolfgang Koehler, Forestry Attache at the German Embassy, and Chief McArdle. Their tour over the Davis County watershed was televised.

Asst. Chief Harper and Dr. Jemison spent 10 days in the Station territory the latter part of September. During their visit watershed management research activities received considerable discussion.

Copeland spent one week in Washington on detail; attended the American Society of Agronomy meeting at Purdue University; and visited all WMR activities at the Station's research centers during the summer.

Richard B. Marston, formerly in charge of the Wasatch Research Center, transferred to the Central States Experiment Station early in September. Dick spent many years in the Intermountain region, and his many friends wish him success in his new assignment.

Publications

Soil-site index studies of western white pine in the northern Rocky Mountain region. Otis L. Copeland, Jr. Soil Sci. Soc. Amer. Proc. 22: 268-269. 1958.

Parrish Canyon, Utah: A lesson in flood sources. Richard B. Marston. Jour. Soil and Water Conservation. 13(4): 165-167. 1958.

The Davis County experimental watershed story. R. B. Marston. Intermountain Forest and Range Experiment Station. Processed publication. June 1958.

At this writing, numerous manuscripts are in various stages of completion, ranging from initial preparation to publication.

Boise Research Center

General

A 2-day show-me trip for Spanish foresters, Arboli and DeJuan, initiated the field season in early May. A late spring left a fairly heavy snowpack in the woods through the middle of may, thus preventing a complete showing of all studies to the Spaniards.

Joe Kidd accompanied the Junior Foresters Management Training group on its 2-week tour of problem areas in Utah and southern Idaho. Everyone seems to have problems in watershed deterioration ascribed to overgrazing by cattle, sheep, deer, elk, and rodents.

The field management training trip was followed by a show-me trip for the range management class from the Utah State University Forestry School. The 24 students were shown the work on the experimental forest and the Little Owl logging road reseeding study.

In September, Copeland visited the Center to discuss the current status and future plans for the watershed management research program. It was decided that the Arrowrock substation study and the basalt soil sediment flow study should be terminated; that pending analysis of this year's data, the Little Owl logging study had yielded sufficient information and should be terminated, with a report on results to follow; that the Bannock Creek sediment study be kept on a standby maintenance basis; and that the Morehead Mountain study be continued for additional periodic measurements. New work planned will involve either the hydrology of ponderosa pine areas, or soil erosion studies on overgrazed forest range, or both, depending on manpower and funds available for such new medium to long-term studies.

A brief summary of summer activities pertaining to the various studies follows:

1. Arrowrock substation runoff plots. (FS-1-w6-1)

   The percent of ground cover on these 4 plots was sampled by taking 2,000 points per plot. The two natural recovery plots averaged 64 percent ground cover; the two reseeded plots averaged 88 percent cover. No soil erosion from any of the plots was noted.

2. Little Owl logging road reseeding study. (FS-1-w6-3)

   Sampling this year was extended to each of the 144 plots, whereas last year only half of these were sampled. The increased number of samples will provide more data for the analysis of variance to determine if small but significant differences might exist between methods of seedbed treatment.

3. Morehead Mountain high-elevation range restoration study. (FS-1-w6-1)

Fertilizing the seeded contour trenches on the Morehead Mountain plant cover restoration study showed the following results with respect to vegetation response.

Treatment	Fertilizer	Plants/sq. ft.	Ground cover	Av. ht. of dom. sp.
			Percent	Inches
I	None	8.9	6.0	7.8
II	46- 0-0	10.9	17.5	11.3
III	0-45-0	12.9	11.5	8.2
IV	46-45-0	13.7	20.7	11.2
V	92-90-0	11.1	18.0	12.8

These results have not yet been analyzed for significant differences, however nitrogen appears to produce marked improvement in plant growth. On sample plots established between contour trenches a distinct downward trend in the amount of plant litter has been observed, although the live vegetation is holding its own or gaining slightly. Grazing has been excluded from this area for three growing seasons.

4. Sediment flows from logging roads on basalt soil. (FS-1-w5-3)

Only 38 cross ditches installed on logging roads on basalt soil had produced measurable sediment flows when examined this past summer. Most of the sediment flows were very short, the road surface had a good grass cover, and little erosion had occurred from spring runoff.

5. Bannock Creek sediment production study. (FS-1-w5-2)

Of the 20 sediment-trap dams examined this summer, only two had any additional sediment in them, and very little at that. A 2.70-inch/hour storm occurred over the forest on September 8, but failed to cause additional sediment movement into any of the basins.

GREAT BASIN RESEARCH CENTER

Snow Control. (FS-1-w7-5)

The last Semiannual report described a snowdrifting fence installed during the fall of 1957 in the center of a large flat on the Wasatch Plateau. This fence, 16 feet high and 60 feet long, was constructed of four tiers of 4-foot slat fence on an aspen pole frame.

The snowdrift induced by this fence was observed periodically last winter. At the time of maximum snow accumulation, snow was 8 feet deep on the adjacent undrifted area, while the induced drift had a maximum depth of 15 feet. On June 7, 1958, the snow from the adjacent undrifted area disappeared. Three days later, the induced drift was measured. The main axis of the drift was 90 feet long, extending 20 feet to the windward side of the fence and 70 feet to the lee. Average water content along this axis was 13 inches. Air temperatures were unusually high during early summer and snowmelt was rapid. The induced drift persisted only until June 17, or 10 days later than undrifted snow. The size of the induced drift was reduced by quartering winds blowing around the ends of the fence. It is quite probable that the induced drift would have extended farther back and would have had a higher water content had the fence been longer than 60 feet.

Data obtained last winter indicate that, on comparable areas, a fence 16 feet high and 400 feet long is capable of drifting and storing 1 acre-foot of water beyond the normal snowmelt period. Such a fence would cost about $1,000 to construct. If we assume that the fence would be serviceable for about 20 years and if we allow $20 a year for maintenance and $30 a year for interest, the annual cost of prolonging the melt of 1-acre-foot of water from an induced snowdrift under these conditions would be about $100. Under more favorable conditions and with improved techniques, the cost of storing 1-acre-foot of water in induced snowdrifts can be reduced considerably below the $100 per year currently estimated. Increasing the fence height seems to be the best possibility of decreasing the cost per acre-foot of stored water. Although the cost of construction increases rapidly with height, it is likely that cost per unit volume of water stored would decrease. Higher fences also have the advantage that the induced drifts would be larger, would persist longer, and thereby delay streamflow longer.

This summer another fence, 300 feet long and divided into 3 sections, was constructed on the Wasatch Plateau. The center section is 21 feet high and the end sections are 17½ and 14 feet high. It is located on a windswept 15 percent slope just below the crest of the plateau. Drifts induced by these three sections, as well as by the fence constructed last year, will be observed and measured for several years. Future plans include the construction of additional fences during the next 2 or 3 years. If results obtained next spring indicate that still higher fences are more efficient, fences as high as 27 feet will be constructed. With present construction techniques, 27 feet represents the maximum practical height.

Pleasant Creek Evaluation Study. (FS-1-w6-1)

Field work for the 1958 phase of the evaluation study of Pleasant Creek restoration project was completed this summer. Robert Thompson, chief-of-party for the 1955 phase, was in charge of the project again this year.

Except for ten infiltrometer plots that were no longer accessible because of the contour trenching, all measurements made in 1955 before treatment were repeated this year. Laboratory work and compilation of data are now under way, and a progress report will be issued early next year.

Preliminary examination of the data shows that the restoration treatment in the subalpine zone has resulted in increased initial infiltration capacity, but in decreased final infiltration capacity. The reasons for the decrease in final infiltration capacity are not clear, but one possible contributing factor is the formation of a plow pan during the restoration operations. We may know more about this when data compilation and laboratory work are completed. Repeat measurements for evaluation purposes are scheduled for 1961.

MISSOULA AND INLAND EMPIRE RESEARCH CENTERS

Road Development Guides. (FS-1-w5-3)

For a number of years, efforts have been made to locate and construct logging roads on forest lands in such a manner to afford control of runoff water and sediment. A number of guides for doing this job, mostly rule-of-thumb ones, have been devised. They were developed, however, without means for specifically evaluating the various soil and watershed characteristics that affect erosion and sediment movement and the relationships between them. For this reason, it is often difficult to determine to what extent proposed road location and design standards will create undesirable erosion and sediment problems.

A comprehensive study was made during the past field season on five major soil groups in Region 1 to develop better criteria for evaluating the probable effects of road construction on soil and water and to provide guides for minimizing or preventing sedimentation damage. This study considers 22 independent watershed characteristics in relation to erosive cutting of road surfaces and the distance of sediment transport downslope from effective drainage features on the roads. These two dependent and 22 independent variables were measured on 120 logging road study locations in each of five major soil groups, important either because they were known to be high erosion hazard soils or because they constituted extensive areas of the forest lands of the Region. The independent variables included such factors as cover condition, soil aggregate stability, slope gradients, cut heights, fill lengths, road widths, drainage intervals, road grade, and number and location of various kinds of major obstacles to sediment movement on fills and slopes below fills.

Theoretical equations expressing the energy relationships of these watershed characteristics to the dependent variables were developed separately for the upper slope, cut slope section, road surface, fill slope section, and lower slope positions with respect to a conventional road cross-section. These separate relationships were then combined into multiple regression equations expressing the effects of the 22 independent characteristics on the dependent ones. Study sites in each soil group were stratified by aspect, by topographic position, and by road grade classes. It is hoped this study will provide a basis for segregating any significant differences in road design standards which may be permissible due to differences in the effects of these features on soil and water movement.

Plans have been completed for the analysis of the data obtained from this study using a 650 IBM computer. Certain observational information was also obtained on each study site for correlations with the quantitative data, in order to furnish a basis for evaluating how well the quantitative relationships existing on the ground can be ocularly judged. From this analysis it is hoped that mathematical alignment charts or some kind of a slide rule can be developed for use as a guide to assist in locating logging roads and prescribing their construction standards to prevent sediment from reaching drainage ways where it can be carried into streams.

Restoring Depleted Watershed Slopes. (FS-1-w6-1)

The first soil movement measurements were obtained this year from the study of the effects of rehabilitation and protection from grazing of the intermediate elevation sagebrush-grass elk winter range in the upper Gallatin River watershed. In 1956, two 3-acre elk-proof exclosures were built on south-facing aspects of this range where elk winter use had depleted the vegetation to a condition where only about 30 percent of the ground was covered by protective plant and litter cover. A part of each exclosure and a comparable area outside were plowed, disked, and reseeded, primarily with intermediate and pubescent wheatgrass, in the fall of 1956. Soil movement plots, 1/50-acre in size, equipped with facilities for collecting soil eroded from the plots, were established both inside and outside the exclosure on reseeded and unseeded sites. Measurements of cover condition and soil movement were made on these plots in late May 1958 after the elk had left the range. At this time, the reseeded plots had had one full growing season. Results of these measurements suggest some initial relationships that are interesting and, perhaps, of considerable importance:

1. Although the reseeded plots showed a tremendous increase in aerial growth of plant herbage, they showed a reduction in ground cover (plant basal area plus litter) when compared to the unseeded plots.

This is attributed to the cultivation treatment which destroyed part of the previously existing ground cover. The reseeded stands have not yet begun to contribute herbage as litter to the ground surface. It is expected that the ground cover on these plots will increase rapidly in the next few years because the grass stand established is excellent.

2. On both study areas the amount of soil eroded under protection from elk use was greater than that outside where elk had grazed and trampled. There was a noticeable loosening of the surface soil by frost heaving inside the exclosures when compared with the grazed plots. This suggests that on sites which have little or no snow cover during periods of alternate freezing and thawing in the spring, mere protection from grazing without cover improvement may produce increased soil movement due simply to loosening of the surface soil.

3. The greatest amounts of soil eroded in each study exclosure came from the reseeded plots. Soil movement from these plots is believed to have been influenced in two ways: First, by the tillage operation during reseeding and, secondly, by frost heaving action which kept the surface soil loose. It is anticipated that control over soil movement will increase rapidly on the reseeded plots as litter cover begins to accumulate on them.

Additional measurements of cover and soil movement conditions over a longer period are needed before definite conclusions can be drawn from these observations.

Cutting Snowpack Timber in Lodgepole Pine Forest. (FS-1-w7-4)

In June, a cooperative project was undertaken with the Division of Forest Economics to evaluate the physical characteristics of eight proposed experimental watersheds in lodgepole pine on the Lewis and Clark Forest by stereophoto methods. Photo evaluation has been completed for 2 watersheds, and is being ground checked to determine the accuracy with which this method can be employed for this purpose. If the accuracy is adequate, similar evaluation will be made of the other watersheds tentatively selected.

Snow Behavior in White Pine Forest. (FS-1-w1-2)

Analysis of the snow accumulation phase of the snow behavior study at Priest River Experimental Forest has been completed and work begun to draft a manuscript. Essentials of this analysis were outlined in the Station's last Annual Report. Analysis of the snowmelt phase of the study was interrupted during the summer because of the heavy schedule on other projects, but will be resumed this winter.

NEVADA RESEARCH CENTER

Watershed Management Research Problems Delineated.

In the last Semiannual report progress in developing a problem analysis for our portion of the Station territory was reported. This analysis has reached the point where three major watershed management problems needing research can be delineated. These are summarized below, including a brief statement of objectives and broad work projects.

1. How to attain the maximum possible control of rain-on-snow (wet mantle) flood runoff from cutover and burned forest and deteriorated rangelands, primarily in the Truckee River basin, is considered to be the most important problem.

   a. Objectives of research: to develop and test methods to guide management in a long-time rehabilitation program in the interest of (a) reducing winter flood volumes, (b) reducing winter peak flows, (c) reducing damage from sedimentation, and (d) minimizing reduction of water yields.

   b. Major work projects planned:
      (1) Inventory of the present vegetation-soil-hydrologic types and conditions within the Truckee basin.
      (2) Studies of methods of restoring control of runoff.
      (3) Studies of hydrologic and erosion processes.
      (4) Small watershed studies for evaluating restoration practices.

2. How to restore control of summer storm (dry mantle) runoff from the cutover and burned forest and deteriorated rangelands, primarily in the Walker, Carson, and Truckee River basins, is the No. 2 problem needing further research.

   a. Objectives of research: to develop and test methods to guide management in a rehabilitation program in the interest of (a) preventing flash flood runoff, (b) preventing damage from sedimentation, and (c) minimizing reduction of water yields.

   b. Major work projects planned:
      (1) Inventory of the present vegetation-soil-hydrologic types and conditions within the dry mantle flood source zones. (This will be an adjunct of the survey phase of the wet mantle flood problem).
      (2) Studies of methods of restoring control of overland flow.
      (3) Studies of micro-environmental factors and related processes.

3. How to improve water yield from uncut forests and associated rangelands, primarily in the Walker, Carson, and Truckee River basins, is the third most important watershed management research problem.

   a. Objectives of research: to develop and test methods to guide management in a long-time timber harvesting program in the interest of (a) improving water yield, (b) improving the timing of spring runoff, and (c) minimizing loss of winter flood control.

   b. Major work projects planned: Research studies undertaken on the east slope of the Sierra Nevada will be coordinated with work being done by the California Cooperative Snow Management project.

Center Office Moved

On September 5, the Center headquarters moved into spacious quarters in the Max C. Fleischmann Building, College of Agriculture, on the University Campus in Reno, thus vacating a building it occupied for 18 months on East Second Street, Reno. Part of the new office-laboratory facilities will serve as the University liaison office of the Toiyabe National Forest.

Extensive dry mantle flooding in August

The seriousness of the dry mantle flood problem was illustrated in striking fashion last month. The Center staff, along with Hallie Cox of the Toiyabe National Forest, toured the Bridgeport (California) district inspecting flood damage and erosion areas resulting from the heavy rainstorms of August 14-18. Damage was extensive: Highway 395 was closed to traffic for many hours, secondary roads were washed out at stream crossings; and one campground was inundated with mud-rock debris. To the north, on the Carson (Nevada and California) district, a tourist was lost when his car was swept off Highway 40 into the Truckee Canyon. It appears that our work is cut out for us.

Survey of Possible Study Areas

This summer afforded an opportunity to take a close look at some potential study sites and experimental watersheds. For 2 days, Copeland and Haupt roamed the Dog Creek watershed demonstration area, northeast of Boca, California, in the Truckee watershed. We found this 16.5-square mile drainage to have many suitable attributes for studies pertaining to the wet mantle flood problem. The area typifies the Truckee basin in that the timber types (Jeffrey pine and Jeffrey pine-white fir) have been largely cutover or burned. Elevations range from 5,500 to over 8,000 feet. Undulating topography characterizes the bottom lands; and slopes rise sharply to form the east face of the Bald

Mountains. Ownership of the land and control of the water rights rest with the Toiyabe National Forest, as does the upkeep of a fairly complete road system. Four subdrainages that show promise for use as small experimental watersheds are located within the main watershed. These will be examined more closely during the 1959 water year.

At the beginning of the 1957 water year, the Toiyabe National Forest, in cooperation with the Geological Survey, installed a streamgaging station near the mouth of Dog Valley. Some precipitation gages were distributed over the watershed. This fall the Forest, with help of the Center, plans to expand the precipitation station network by adding five more seasonal gages.

WASATCH RESEARCH CENTER

Use of a Neutron Soil Moisture Meter. (FS-1-w1-7)

The first set of neutron meter soil moisture readings in connection with the evapotranspiration study in mountain brush and aspen was completed on August 8, 1958. A partial set of soil samples was obtained at the same time for moisture determinations by gravimetric procedures. About two-thirds of the soil moisture measurements made by the neutron meter were higher than those obtained on gravimetric samples with which they were paired. Occasionally, moisture contents determined by the meter were several times as great as those determined on samples gravimetrically, but rarely were they less than one-half as great. Moisture contents and correlation coefficients that express the relation between soil moisture contents, as determined by the two methods, are shown in table 1.

Table 1.--Comparative soil moisture contents determined by gravimetric sampling and by neutron meter readings, July 29 to August 8, 1958

Block	Vegetation	Observations	Av. water content per foot of depth		Correlation coefficient
			Samples	Neutron meter	
		No	Inches	Inches	
I	Aspen	48	1.031	1.387	0.656**
II	Mtn. brush	44	.844	1.613	.715**
III	Aspen	39	.876	1.693	.355*
IV	Mtn. brush	31	.712	1.051	.045
V	Aspen	38	1.170	.895	.433**
VI	Mtn. brush	36	1.381	.854	.625**
		Average	1.002	1.249	

*Significant at 5 percent level
**Significant at 1 percent level

Moisture contents determined by both methods showed as much as 115 percent variation between duplicate samples. Greatest variation in moisture determinations made by the neutron meter occurred near the surface of the soil profile, whereas gravimetric sampling showed greatest variation at the lower depths. Almost as much time was required to make the set of readings with the neutron meter as to take the gravimetric samples.

In another study four different types of access pipes were placed to a 5-foot depth in the corners of a 3-foot square pit. A set of 1-minute readings made on August 12, 1958 in the different access pipes was compared with a set of 2-minute readings made on the same day, and with a set of 2-minute readings made on the previous day. Total water content in the 5-foot soil mantle, as determined by the 3 sets of neutron meter readings in each of the 4 access pipes, was much greater than that determined by duplicate gravimetric samples taken on August 11. Total moisture shown by 2-minute readings on August 12 was higher than that shown by 2-minute readings made the day before. Total moisture by 1-minute readings was even higher than that determined from the 2-minute readings made the same day, although they were separated by only short time intervals (table 2).

Table 2.--Moisture content in a 5-foot mantle of mountainous soil as determined by various procedures

Sampling methods	Inside diameter of pipe	Water content
	Inches	Inches
Gravimetric samples, August 11, 1958		4.6
2-minute readings on August 11, 1958		
A. Electric metallic tubing	2 1/16	6.8
B. Pressed tar paper sewer pipe	4	7.2
C. Stainless steel pipe	2 1/2	6.1
D. Corrugated rain gutter pipe	3	6.2
2-minute readings on August 12, 1958		
A. Electric metallic tubing	2 1/16	6.8
B. Pressed tar paper sewer pipe	4	8.1
C. Stainless steel pipe	2 1/2	6.5
D. Corrugated rain gutter pipe	3	7.6
1-minute readings on August 12, 1958		
A. Electric metallic tubing	2 1/16	7.4
B. Pressed tar paper sewer pipe	4	8.5
C. Stainless steel pipe	2 1/2	7.2
D. Corrugated rain gutter pipe	3	7.9

Discussion of Meter Operation

The measurements made with the neutron meter are of an exploratory nature. Although a significant relationship exists between the moisture determinations by the neutron meter and by paired gravimetric samples, replicate determinations exhibited wide variation.

Material used for access pipes to accomodate the probe should be as nearly like that used for calibration as possible. If the pipes used in field installations differ greatly from those used for the initial calibration, the probe should be recalibrated. The diameter of an access pipe should be just large enough to permit the probe to fit inside. Pipes should be driven into the soil, where possible, to provide firm contact with the soil. Corrosion of the pipes will not affect the counting rate unless it forms a hole in the pipes that permits water to seep inside. Free-water causes erroneous counts, whether it seeps in or condenses on either the inside or outside of a loose-fitting pipe.

The original cost of a neutron soil moisture meter is high and upkeep costs will probably be high because most repairs must be made by highly skilled personnel. Careless handling could result in serious biological damage to any person contacting the probe frequently. Careful consideration should be given to the kind of soil to be sampled, to the feasibility of other methods of sampling, to the long-term economy, and to the potential radiation hazards before a neutron soil moisture meter is purchased.

LAKE STATES FOREST EXPERIMENT STATION

WATERSHED MANAGEMENT RESEARCH SEMIANNUAL PROGRESS REPORT
April 1, 1958, to September 30, 1958

La Crosse Research Center

A New Center is Born

La Crosse, Wisconsin, on the east bank of the Mighty Mississippi is now the home of the Lake States' newest forest research center. Dick Sartz, worn out and beaten after his trip from New Hampshire with four kids, a dog and two birds (their two cats were shipped by rail) arrived on September 1st to head up the new unit.

So far the staff, consisting of Sartz, has been up to its neck in the countless chores connected with setting up an office, interviewing stenos, buying supplies, and at the same time trying to acquaint itself with the area and its peculiar problems.

This is the "Coulee Region," geologically known as the Driftless Area. It is an unglaciated island of some 7,000,000 acres, mostly in Wisconsin, but also extending across the Mississippi into the southeastern corner of Minnesota and into northeastern Iowa and down into Illinois. By some mysterious quirk of nature, the continental glaciers by-passed this area leaving a dissected plateau, now weathered into an intricate drainage pattern. The hill-tops and valley bottoms are both flat, and for the most part farmed. The steep slopes in between are forested (or should be) and for the most part grazed and in other ways abused. This two-storied type of farming on highly erosive soils has resulted in widespread and spectacular erosion--the worst of which is found on the wooded slopes. The predominant forest is oak-hickory.

Geologically, the area is fascinating. A loess mantle of varying thickness rests on a relatively thin limestone cap. This is underlain by sandstone, which in places is very soft and easily broken. Both formations are in horizontal strata. The forest soils were derived mostly from the sandstone, hence their high erosibility.

The watershed management research job here is written all over the land. But the solutions may not be so obvious. They may require techniques that are as yet untried in our field.

Our first big job will be to select areas for study. Joe Stoeckeler has done most of the bull work connected with this, but the final selection still has to be made. Sartz has made a start and is hopeful that final selection can be made this fall or early winter. The Wisconsin Conservation Department will buy the land and cooperate with us in other ways.

-- R. S. Sartz

Grand Rapids Research Center

New Studies

A preliminary study concerning ground water relationships between bogs and adjacent uplands has been established during the past summer. Two transects of wells on either side of a black spruce bog have been set up. Each transect extends from within the upland into the middle of the bog. Wells were placed by augering with a barrel soil auger or by driving well points to the water table. One well has been equipped with a Stevens type A35 recorder.

This is a quite simple study which is just a step into the big problem of swamp hydrology. We hope to accomplish several objectives--to learn what relationship exists between the water table in a bog and the water table under the adjacent uplands (or perhaps if it's the same table do they still fluctuate the same), and also to learn something about instrumentation techniques concerned with ground water measurement in a swamp.

The problems concerned with swamp hydrology are relatively new to watershed management research in the U. S. Within the state of Minnesota we have several million acres of swampland with over one million acres of commercial black spruce swamp land in the northern portion. We're the top of the watershed for three major drainages, the Mississippi, Great Lakes and St. Lawrence River, and the Red River of the north. Yet we know almost nothing about the hydrology of our area. This is the only such area in our country so background information is limited.

Rather than becoming bogged (notice pun!) down in the midst of a large scale experiment in swamp hydrology we have elected to get our feet wet slowly (and literally) by collecting information about relatively simple relationships and by working out instrumentation techniques on a small scale. This first study is only a beginning. But already it has started the mental wheels turning. One big problem which we like to throw out to watershed brains concerns the techniques of measuring rate of ground water flow in a swamp. Especially in a large bog of several hundred to a thousand acres with five or six different outlets. Perhaps even a simple method of measuring relative rates of flow before and after treatment would meet our needs. Other problems concern varying peat permeabilities, different types of bog bottoms, and general swamp ecology dealing with sphagnum build-up and peat formation will be cropping up in the future. We know we'll never be "swamped" with answers to questions such as these but we are beginning the search for the answers.

Soil Moisture Studies

Soil moisture samples were collected under a number of cover conditions and a range of stocking levels within certain forest types for the second summer. This is a continuation of work mentioned in other reports.

Analysis has not been completed. Much of this work was carried on by summer student, Clyde Shumway, a budding watershed researcher now studying at the University of Minnesota.

Publications

Bay, Roger R. 1958 Cutting methods affect snow accumulation and melt in black spruce stands. U. S. Forest Serv., Lake States For. Expt. Sta. Tech. Note 523, 2 pp. (Processed)

Bay, Roger R. 1958 Forest type affects snowpack. Jour. Soil and Water Conserv. vol. 13, No. 3.

-- R. R. Bay

East Lansing Forest Research Center

General

The watershed program of the East Lansing Research Center has taken several big steps in the past six months. This summer has seen a continuation of Bob Dils' efforts towards the completion of a problem analysis of watershed management research needs in Michigan. Our load of chores was also lightened by the presence of summer student Ross Whaley, University of Michigan senior, who took over weather station maintenence and soil moisture measurements. Of major importance was the arrival of Dean Urie whose presence now doubles our staff of technicians.

On loan from the St. Paul office is Joe Stoeckeler who has been burning the midnight oil in an attempt to locate representative areas worthy of future research. This problem is considerably complicated by the extremely varied nature of Michigan's soils and geology. The geology of the northern half of the Lower Peninsula ranges from dry, sandy outwash plains to steep rolling moraines with a large area of intergrade or mixture of these forms. Associated with these forms are areas of wetlands predominantly hardwood swamps. Of immense value in selecting sample areas has been the acquisition of advanced sheets of topographic maps from the USGS. Mapping of northern Lower Michigan is still in process and very few quadrangles have reached final form.

Stream Bank Survey

An evaluation survey of stream improvement work has just been completed. The Michigan Department of Conservation has had a program of stream improvement in action since 1950. Work done by the MCD consists of (1) stream structures and (2) upland works. Upland works consist of tree planting, gulley control, and stream fencing. Stream structures include instream structures such as dams, deflectors, stump covers, and log booms, as well as bank stabilization structures such as rock riprap, log jetties,

log-sod covers, and sheet piling. Seeding and fertilization is done in conjunction with all bank stabilization structures. Our survey was concerned only with the effectiveness of bank stabilization practices as a means of controlling bank erosion and thus decreasing sediment production. A total of 107 treated and 80 untreated banks from four watersheds were examined. Information recorded from each bank includes slope, aspect, bank height, general soil texture class, an estimate of vegetation density and composition, and estimates of total stream bank erosion and degree of waterline erosion.

Banks selected for sampling were predetermined from MCD stream structure field sheets and were balanced as well as possible according to aspect, height, and soil texture class. Though analysis is far from complete, the differences between treated and untreated banks is striking. Waterlines on the treated banks are 93% stabilized while untreated banks have 30% waterline stabilization. Untreated banks are 47% seriously eroded (gulleys, slumps or soil slippage, and undercutting) as compared to 9% in the treated banks. The factors of slope, soil texture, and bank height have not yet been evaluated as to their effect upon success of stabilization.

Soil Moisture Variability

As part of our soil moisture studies, an investigation of soil moisture variability under forested and non-forested conditions at the beginning and the end of the growing season has been completed. Forty soil moisture samples were taken from a one-acre plot in a scrub oak forest and a corresponding number were taken from an adjacent abandoned field. Sampling was done on May 8 and September 19. Soils sampled are classified as Grayling sand and are deep glacial outwash sands with little profile development and no discernible variation between plots. Several intensive "point" samples were also taken from each plot for the purpose of comparing areal moisture levels and variation to that encountered in a small sub-plot or point. Results are outlined in the following table.

MAY 8

Soil Depth (feet)	Forested $\bar{x}$	Forested s	Forested $s/\bar{x}$	Nonforested $\bar{x}$	Nonforested s	Nonforested $s/\bar{x}$
	Percent	Percent	Percent	Percent	Percent	Percent
0-1	8.3	0.94	14.9	7.0	0.58	9.2
1-2	6.1	.79	12.9	5.6	.63	11.3
2-3	4.4	.63	14.3	4.1	.43	10.5
3-5	4.2	.38	9.1	3.8	.29	7.5
5-7	4.1	.54	13.3	4.1	.44	10.7
Av.	5.5	.66	12.0	4.7	.47	10.1

SEPTEMBER 19

0-1	4.1	.32	20.0	5.3	.47	8.8
1-2	2.5	.63	25.2	2.3	.70	30.4
2-3	1.6	.53	33.1	1.8	.46	25.5
3-5	1.9	.67	35.2	2.7	.57	21.1
5-7	2.3	.57	24.8	3.0	.49	16.3
Av.	2.4	.64	27.2	3.0	.54	20.4

As is easily seen, moisture contents in these sandy soils have a small depletion range. Variation is slightly higher in the forest as compared to the non-forest (grass). Surprisingly, standard deviations (s) show little change at the end of the growing season despite the lower moisture contents. Coefficients of variation ($s/\bar{x}$) are nearly double those encountered in May. Comparison of soil moisture levels and variation values reveal that, as would be expected, variation is somewhat lower in the twelve-foot circle as compared to the one-acre plot. Average moisture contents for the entire profile compared favorably between point and areal samples, however, individual values varied significantly.

-- Dave Striffler

NORTHEASTERN FOREST EXPERIMENT STATION

Division of Watershed Management Research

Semi-annual Report October 1958

GENERAL

The one-armed paper hanger had nothing on the sheer busyness of the Division Staff in Upper Darby during the past six months. He was busy--too busy to get work done. Busyness is probably responsible for as much unanalyzed data as are recorder clocks.

Busily, we can report that:

Dick Sartz and family transferred to Lake States. (Just a year ago we reported that Dick had taken over the Hubbard Brook Project). Sid Weitzman's Lake States program gets a good man, and Bob Pierce, veteran of Vicksburg and long time (4 years) Hubbard Brooker is our new project leader.

In April, Sartz, Reinhart, and Lull visited Coweeta and the Washington Office to inquire into ways and means of analyzing fast-accumulating watershed data. From this came Reinhart's tests with the discharge integrator (the Washington Office has distributed copies of his report), and our current efforts to line up the 7-year - 5-watershed Fernow records for electronic computation.

The cooperative watershed research program is moving along. Baltimore started gaging two watersheds this summer, Newark poured 3 weirs, and State College completed 2 weirs.

Clark Holscher toured our region in September in a functional inspection that included attendance at two watershed meetings and stop-overs at Hubbard Brook, Newark, Baltimore, Kingston, State College, and Elkins.

In May, Lull accompanied Norman Tripp on a watershed management inspection of the Allegheny National Forest. One of the questions, for research was: Why does the pH of a stream in a recently cutover watershed suddenly drop during storm discharges? Such pH changes had been highly destructive to a trout hatchery downstream. Also, up for consideration was the effect of the clear-cut power and gas lines that criss-cross the Forest. For that matter, what is the hydrological-effect width of a road? Or its depth?--if you consider rainfall interception by 6-lane traffic.

KINGSTON RESEARCH CENTER

Leading Ridge Watershed

Weirs were begun and completed on Watersheds No. 2 and No. 3 this summer. The Pennsylvania Department of Forests and Waters constructed another all-weather road to the sites and construction proceeded smoothly. The weirs are similar to the one on Watershed No. 1, 90 degree V-notch set in a Trenton cross section. They are low because of the low gradient and low banks. Both weirs are keyed into the shale bedrock. Each of the three experimental watersheds are about 300 acres in area.

Dedication of the project took place on September 12 in a ceremony that highlighted the annual meeting of the Pennsylvania Forestry Association. Representatives of the School of Forestry of the Pennsylvania State University, the Pennsylvania Department of Forests and Waters, and the U. S. Forest Service, agencies cooperating in this project, participated. Dedicatory addresses were made by the Honorable Maurice K. Goddard, Secretary of the Department of Forests and Waters, Dr. Ralph W. Marquis, Director of the Northeastern Forest Experiment Station, and Dr. Eric A. Walker, President, Pennsylvania State University. Herbert C. Storey, Director, Division of Watershed Management Research, U. S. Forest Service, delivered the Association's banquet address.

Beforehand, Reigner participated in a panel describing the project, along with Gene McNamara, and Dick Byrnes. Following the ceremony Byrnes and Reigner conducted a show-me trip around Watershed No. 1.

Streamflow records are now being produced at all three watersheds.

Pocono Experimental Forest

A group of professional dam builders (regular beavers) moved onto the Pocono watershed this summer; apparently they were not satisfied with the amateur job of the weir builders. The beavers have become established in large enough numbers to become nuisances and have resisted the efforts of the local game protector at trapping them out or otherwise discouraging them. This summer's streamflow records are good time clock reports of the beavers' work schedule. Analysis is not contemplated.

A working plan was prepared and approved for a soil survey of the Pocono Experimental Forest this summer. Mapping was to be done with the same intensity and under the same general classification scheme as that used locally for agricultural areas under the national cooperative soil survey. Most of the soils found on the forest have been identified and some mapping of soil boundaries has been done.

Watershed Calibration

Reigner presented a paper Prediction of streamflow for single watershed calibration at the annual meeting of the American Geophysical Union in Washington on May 6. Since then, further refinements have been made in readying the procedures for manuscript presentation.

These recent analyses indicate:

1. Soil moisture has no direct effect on streamflow at Dilldown. It does have an effect on groundwater storage changes, but no additional effect on streamflow.

2. There are consumptive use losses from streamflow during May through November. These are in addition to losses from storage and are probably riparian use losses. But there are no such losses in December through April.

3. Groundwater depletion and recharge proceeds at a different rate in October from that in June through September. This is probably due to reduced transpiration by the predominately deciduous vegetation.

Miscellaneous

John Kalafus, who recently received his Master's degree at Yale, has been assigned to the Dilldown watershed project by the Pennsylvania Department of Forests and Waters. John thus assumes the duties vacated by Gene McNamara who is now District Forester at Stroudsburg.

Irv Reigner addressed the Forestry School convocation at Penn State in April. A week later he addressed Hal Wilm's class in Watershed Management at the New York State College of Forestry of Syracuse.

Reigner and Lull visited the Wild Creek watershed and the reservoirs belonging to the Bethlehem Water Authority. Bud Frantz, formerly the INCODEL forester, is now assistant Executive Secretary of the Authority.

ELKINS RESEARCH CENTER

Treated Watersheds

During the last year our commercial clear-cut and diameter-limit cut watersheds have been logged. We are presently cutting one of the selectively-marked watersheds and before New Year will go into the intensive management watershed. Logging on this last watershed will be handled in a manner prescribed for municipal watersheds. Results to date indicate that where logger's choice roads are used, such as in the clear cutting and diameter limit cutting, water quality suffers. Since the

start of logging, 105 water quality samples were taken on the clearcut watershed with concurrent samples on the control. The following tabulation shows number of samples in each turbidity unit class:

	Turbidity Unit Classes*						
	0 - 9	10-15	16-99	100-999	1000-1999	2000 and up	Total
	(Number of Samples)						
Clearcut	13	12	28	36	7	9	105
Control	101	4	0	0	0	0	105

*Turbidity scale of the Jackson turbidimeter.

One of these samples from the clearcut watershed had over 50,000 parts of soil per million parts of water by weight.

After start of logging, 23 samples from the diameter-limit and control watersheds were taken with the following results:

	Turbidity Unit Classes					
	0-9	10-99	100-999	1000-1999	2000 and up	Total
	(Number of Samples)					
Diameter-limit	1	6	9	1	6	23
Control	23	0	0	0	0	23

The dirtiest sample from the diameter-limit watershed measured 48,000 p.p.m. by weight.

A little more than a year has elapsed since start of logging in the clear-cut area. Logging started on May 15, 1957 and was completed on June 15, 1958. The records show:

	Streamflow		
	Predicted*	Measured	Increase
	(Area Inches)		
May - Oct. 1957	2.5	3.8	1.3
Nov. 1957 - April 1958	16.5	17.4	0.9
May 1958	3.0	3.1	0.1
June 1958	1.8	3.1	1.3
July 1958	4.0	5.6	1.6
Total			5.2

*If watershed had not been cut.

These figures are still tentative and must be considered so until additional analysis is done.

Discharge Integrator

Ken Reinhart spent a lot of time working with a discharge integrator (the type used by the U.S.G.S.) and prepared a report as to its possible uses in streamflow computations. We are not able to make much use of an integrator for the bulk of our data represents flows lower than those for which the instrument was designed.

Meetings Attended

Yawney and Phillips attended the meeting of the Northeastern Forest Soils Group at Amherst, Massachusetts.

Reinhart and Phillips attended the annual meeting of the Northeastern Forest Nurserymen held in Parsons. Reinhart participated in a panel on soil moisture. Phillips assisted with exhibits of measuring instruments.

Hart, Yawney, Reinhart and Trimble attended some of the sessions of the annual meeting of the Interstate Commission on the Potomac River Basin at Blackwater Falls, West Virginia.

Miscellaneous

John Phillips has completed the original humus measurements on the watersheds. He has also been busy this summer with soil moisture measurements, but considerably less busy than he would have been if we had not had such an extremely rainy summer. Over 12 inches of water fell on the Fernow Experimental Forest in July and almost 16 inches on the nearby Clover watersheds.

During the last four months more people have visited the Fernow Experimental Forest, and show-me trips have taken a larger percentage of our time than during any comparable period since the Center was established. Over 200 people in 25 separate trips have visited the area. The largest group was the Interstate Commission on the Potomac River Basin--three bus loads.

The Soil Conservation District Supervisors from nearby counties spent a half day going over our research.

Mrs. Kathleen G. Polino has been added to our staff as a career-conditional employee. Her principal interest and work is watershed management records.

LACONIA RESEARCH CENTER

Integrated Plot Studies

Ray Leonard initiated a study this summer at Hubbard Brook to determine net rainfall in a northern hardwood forest. Throughfall is measured on three one-half-acre plots set off in ten-foot grid sections. Five standard rain gages are placed at the centers of randomly drawn grid squares in each plot. After storms of 0.30 inch or greater, each of the gages is measured, emptied and moved to the center of the next randomly selected grid square.

Stemflow is measured in isolation strips adjacent to the plots. Two groups of trees, 28 in all, have been "tapped." All of the principal hardwood species found in this vicinity are represented. Diameters range from 1.5 inches to 16.0 inches. To collect stemflow, trees were fitted with zinc collars varying in width from 3/4 of an inch to 2 inches. Plastic hose leads the water from collars to storage containers. Calibrated 55-gallon drums equipped with a ruled stick attached to a float are used to store and measure the water collected from large trees. Stopcocks at the base of the drums permit convenient draining. Smaller trees are equipped with gallon cans, as storage containers, that are weighed and emptied following each storm.

Gleaned from the study so far:

1. Yellow birch (a rough bark species) has 50% less stemflow than other species.

2. Stemflow from one 10-inch beech amounted to 52 gallons for a 1.24-inch storm.

3. Approximately 4% of gross rainfall appears as stemflow.

4. 70% of gross rainfall appears as throughfall.

5. Interception apparently accounts for 26% of gross rainfall.

Roads, Trails, Adminstrative Site

Accessibility into Hubbard Brook is improving by leaps and bounds. The latest section of our main road was completed in August opening up a total of about four miles of all-weather road to the interior of the watershed. A surface coat of crushed rock will be applied this fall to complete this section.

Our newly acquired weasel has opened new horizons in our approach to servicing gages during the winter months. With the assistance of a trail crew and a bulldozer we cleared a weasel trail to the most weather stations. Using the weasel over-snow vehicle considerably reduces travel (snowshoe) time.

Praise Allah! We now have an administrative site! The final transactions have passed--the deal is signed, sealed and delivered. The property we acquired is a 128-acre tract of land adjacent to the experimental watersheds. We plan to develop much needed administrative buildings on part of the land and possibly use other portions for an additional gaged watershed.

Weir and Calibration Flume

Our fourth weir is still on the drawing boards. The engineers in the regional office have relieved us of the chore of getting out bids for our next weir on a contract basis. It is hoped that these bids will be let early next spring. An access road to this weir site was constructed this summer.

In the past we have calibrated our 90-degree and 120-degree sharp-crested weirs by collecting the water flowing over the blade for a given period of time, weighing the water and then converting the weight to a volume measure. By knowing the gage height at the time the water was collected a stage height-discharge relationship can be established. This procedure can be used to determine the discharge rating curve up to approximately 0.4-foot head. At stage heights greater than 0.4 foot the above method becomes impractical because of such large volumes of water. Rather than depend on a theoretical rating curve for stage heights above 0.4 we have constructed calibration flumes in the stream channels immediately below the weirs. All water passing the blade is funneled through an elongated open-top concrete flume. The flume is uniformly one foot square in cross section in the lower portion, and 1.5 x 3 feet in the upper. A pygmy current meter is used to measure the velocity of the water passing through the flume. These flumes should help us determine actual discharge for stage heights between 0.4 foot and 1.5 feet to 2 feet.

Landslides

A cooperative study of landslides has been completed with Duke University. Edward Flaccus, a graduate student in the Botany Department at Duke, made an extremely interesting and worthwhile study of landslides

as a doctoral dissertation. The title of his thesis is: Landslides and their revegetation in the White Mountains of New Hampshire. The thesis will be microfilmed and Ed plans to publish the results in an appropriate journal.

Miscellaneous

April 13-18--Sartz visited the Fernow Experimental Forest, Coweeta Hydrologic Laboratory and the Washington Office in company of Lull and Reinhart in efforts to evaluate the discharge integrator and IBM devices for tabulating and computing runoff.

April 15--Pierce presented a talk to the New Hampshire Natural Resources Council at Concord, New Hampshire on Watershed Management Research in the White Mountains.

August 26-28--Pierce, Leonard and Federer (summer student trainee) attended the Northeastern Forest Soils Conference held in Amherst, Massachusetts.

September 2-3--Pierce and Lull attended a meeting in Amherst, Massachusetts held to determine the feasibility of establishing a forest watershed research program under the auspices of the Massachusetts Water Resources Commission.

September 8-11--Pierce attended the North American Forest Soils Conference in East Lansing, Michigan.

PUBLICATIONS

Municipal watersheds in the Northeast. Howard W. Lull. Jour. Amer. Water Works Assoc. 50: 979-982.

Forest watershed management research in the ridge and valley section of Pennsylvania. Irvin C. Reigner, William R. Byrnes, and E. F. McNamara. Northeastern For. Exp. Sta., 7 pp.

Influence of land use and forest condition on soil freezing and snow depth. Robert S. Pierce, Howard W. Lull, and Herbert C. Storey. Forest Sci. 4: 246-263.

Management problems and opportunities on forested watersheds in the Northeast. Proc. Soc. of Amer. Foresters, 1957 meeting: 30-32. Norman R. Tripp and Howard Lull.

Manuscripts submitted

Poor logging muddies water supplies. Kenneth G. Reinhart and John R. Phillips.

Better water through forest management. Howard W. Lull.

PACIFIC NORTHWEST FOREST AND RANGE
EXPERIMENT STATION

Semi-annual Report
Watershed Management Research

April 1, 1958 - September 30, 1958

General

These are the doings that have made news here in the past six months:

1. Since mid-July Dave Wooldridge has acted as leader of the Mid-Columbia Center to fill the gap left after George Garrison transferred to the Blue Mountain Center. In addition, he acted as construction foreman, strawboss, and carpenter during construction of three debris catchment dams in Mission Creek.

2. In September, Norman Miner took off for the University of Washington to start work on his Doctor's degree. He will be on leave of absence for at least 20 months. We have installed Dan Bishop as his alternate at the Blue Mountain Center.

3. Jack Rothacher served as Secretary of the Society of American Foresters, Division of Watershed Management during the past year and attended in that capacity during the annual meeting at Salt Lake City. Jack has also been busy working out details of the timber sale which will give us our first treatment on one of the small watersheds on the H. J. Andrews Experimental Forest.

4. Gene Herring is continuing in the role of inventor and has come up with some interesting devices for measuring runoff and erosion. He goes into more detail in his report which follows.

5. Bethlahmy has been working hard as program chairman for the Northwest regional meeting of the American Geophysical Union. In addition he spoke at the national convention of the ASCE on the subject of forest and water yield. In April he prepared a paper which Bernard Frank delivered at the national AGU meeting last May.

6. In September Dunford attended the North American Soils Conference at Lansing, Michigan where he presented a paper on soil problems of the Northwest.

BULL RUN PROJECT

--- by Nedavia Bethlahmy

Forest Corridors and Snow Accumulation (FS-1-w7-4)

We are making plans for some snow studies in an old-growth Douglas-fir stand just outside the Bull Run watershed. A sale area has been selected and within it we have laid out corridors of varying widths oriented on an east-west axis. The object is to determine the effect of strip width on snow accumulation and melt rates. The field lay-out was accomplished with the help of personnel from the Mt. Hood National Forest (Zig Zag Ranger District). Sale of the timber has been delayed by right-of-way problems.

Rehabilitation of Abandoned Logging Roads (FS-1-w6-3)

Sixty blocks were established on an abandoned logging road to determine the effects of scarification and application of NPK fertilizer on the establishment of grasses. The road was scarified with a hand rake, but because the surface was so hard and unyielding, about all we could do was clear the road of large and small branches. Fertilizer was applied at the rate of 450 lbs. per acre, and consisted of a 6:10:4 commercially available fertilizer. Seeds were hand-broadcast at the rate of 7 lbs. per acre and consisted of Tualatin oat grass (2 lbs/A), Alta fescue (2 lbs/A), English ryegrass (1 lb/A), pasture white clover (1 lb/A), and Alsike clover (1 lb/A).

Analysis of the data indicated that scarification affected only the clovers, but they still developed poorly. Fertilization brought about a good development of a grass cover, and we therefore concluded that in the Mt. Hood area abandoned logging roads must be fertilized to insure the development of a grass cover.

Erosion from Logged Lands (FS-1-w5-2)

Natives of the area state unequivocally that our heavy soils are not erodible. In this preliminary study, measurements were made along transects in four types of land conditions resulting from logging, including exposed mineral soil, soil covered with logging waste (litter, bark, wood), troughed mineral soil (resulting from logs being pulled up-hill by the high-lead method), and cat roads. The percent of the logged area occupied by each of these land conditions was determined by a land survey. Preliminary analysis of the data indicates that soil movement occurs throughout the logged area, as indicated in the following table:

Average depth (inches) of soil movement			
Cat road	Bare	Covered	Troughed
.225	.276	.309	.268

Considering the area occupied by each land condition type, we have found that a considerable quantity of soil moves after logging: 44 tons per acre in one rainy season.

Using Hexadecanol to Decrease Evaporation (FS-1-w1-7)

In this experiment two standard Weather Bureau pans were placed side by side; one contained clear water, the other was covered with hexadecanol. The molecules of this long-chained alcohol are characterized by a hydrophylic and hydrophobic end, and therefore tend to align themselves vertically over the water surface in a layer only one molecule thick. Our experiment corroborates other work done in Australia, Texas and Oklahoma. The data indicate that hexadecanol reduces evaporation by 42 percent. We recommend the use of this chemical to reduce evaporation from ponds and small reservoirs.

Instrument Kinks

An instrumentation problem which has plagued us for several months has turned out to have a rather simple solution. The culprit was a new A-35 recorder which kept stopping at frequent intervals. Experts from the Leupold-Stevens Company finally concluded that the trouble was caused by anchoring the end of the clock-weight cable to the bottom of the instrument case rather than to the supporting table. As a result, increased stresses were set up in the instrument restricting free movement of the chart-drive mechanism. Just a hint in case someone else has a similar experience.

Inter-Service Relations

Close relations are being maintained with staff and District personnel of the Mt. Hood National Forest. Aside from routine conferences and job contacts, the following special items deserve mention: 1) Mt. Hood forest rangers convened for a special watershed-management conference, at which time we lectured on our research program; 2) the forest supervisor held a special staff conference relating to watershed problems in the Bull Run area; 3) an all-day hike was made with staff and District personnel over a proposed major access road to determine major watershed problems that may arise. The question of culverts versus bridges was discussed. Paul Neff, the supervisor, would like to see more bridges and fewer culverts installed.

MID-COLUMBIA RESEARCH CENTER

--- by Dave Wooldridge

Testing of a Wetting Agent (Aqua-GRO) (FS-1-w6-1)

This spring Aqua-GRO was applied to an area of exposed mineral soil derived from Swauk sandstone on a 30 percent slope. Infiltration

tests were made several days later, after the soil had dried. We applied artificial rain at a rate of 1/2 inch in 5 minutes, using a hand pump garden sprayer on 1' x 2' plots. Following this we took soil samples from treated plots after excess moisture had drained away.

Results of testing are summarized below:

Item	Treated	Control	Diff.	Diff. required for sig. at .05 level
Infiltration (inches per hour)	4.92	3.54	1.38	0.70
Sediment (volume in cu. cm.)	81	234	153	95
Runoff (total in ml.)	415	965	550	277
Total soil porosity percent	56.2	54.9	1.3	3.1
Macro pore space percent	42.3	39.0	3.3	5.4
Micro pore space percent	13.9	15.9	2.0	3.8
Field moisture capacity percent	10.2	11.4	1.2	2.3
Mean weight - diameter of aggregate (mm.)	0.76	0.82	0.06	.07
Bulk density	1.359	1.394	0.035	0.077

These data indicate that application of Aqua-GRO had highly significant effects on surface runoff, infiltration rates, and sediment production. Some effect on soil properties tested are also indicated.

Sediment Production Study (FS-1-w4-2)

This summer we set out to get some measure of quantities of soil being moved by water and gravity on the slopes of Mission Creek watershed. The dominant soil has a light sandy texture - a very unstable product of Swauk sandstone. Timber-cutting, fires, and grazing have added to the instability, especially on south- and west-facing slopes.

We selected three contiguous drainages with areas of 0.96, 2.39 and 1.43 acres and used about 2 thousand board-feet of 2x6's and 1x6's along with 30 pounds of nails, some tar and tar paper, to construct a sediment catchment dam in each drainage. About 500 cubic feet of storage capacity is provided by each one. After we learn something about "normal" erosion characteristics of these areas, some years hence, we plan to treat two of them to control erosion.

Experimental Watersheds

For three years we have been eyeing the possibility of establishing some experimental watersheds tributary to the Entiat River north of Wenatchee. For several reasons we have not jumped into this project earlier. One big reason has been the matter of access -- the

sheer problem of getting materials to the gaging site. The watersheds we have in mind are hanging valleys - a common characteristic in this glaciated country. Gaging sites are not much more than 500 feet north of the road which runs up the main valley but they are roughly 1000 feet above it!

We have decided the project is feasible and have gone ahead with detailed site plans for the weirs. The only practical way to get building materials to the weir sites is by packing in over steep trails. In view of this we have been exploring the possibility of building weir cutoff walls with steel reinforced concrete blocks. We will appreciate comments from anyone who has had experience with this type of construction.

About the Use of Fertilizers (FS-1-w6-1)

We have tried using fertilizers to re-establish perennial grass cover in several denuded areas in Mission Creek watershed. We have failed to establish the desired perennial grass, but the fertilization itself has been quite successful in stimulating the growth of annual vegetation and thus furnishing good cover for at least part of the year. The trials to date indicate that fertilizers are a very promising means of re-establishing vegetation on denuded and eroding areas. The questions are; What elements should be added: How heavy an application of each element? And, in what chemical form should the element be?

Of the major essential elements, varying levels of N, P, and K can be widely used and in most cases solve the problem. To decide on a fertilizer treatment by any means other than just guessing represents quite a problem in itself. If a soils analysis is available, interpretation of the results will depend on; (1) how the soil was originally sampled, (2) how it was treated following sampling (especially true in determining NO_3 and NH_3), (3) pretreatment of samples (drying and grinding), (4) extracting solution used, and (5) quantitative method of determining the various chemicals.

If we then attempt to balance our soil analysis data against the unknown nutrient requirements of the various plants and trees we are again faced with several problems. In what chemical form are the nutrients available? What is the proper balance between levels of various nutrients? What point in the range of plant nutrient requirement are we attempting to find, the minimum for survival or just some level of satisfactory plant development?

In spite of the above complications, standardized methods of soils analysis and establishment of minimum plant nutrient requirements in terms of both soil and foliar analysis are the only acceptable means of facing our fertilization problems. As these analyses are not available we will continue to make qualified guesses as to elements and levels of use.

Heat Radiation and Soil Moisture (An extra-curricular study - no plan - no project number)

Is there any effect of heat radiation on soil moisture other than those related to temperature changes? The reason for this question stems from observations made recently while sterilizing soil in clay pots for growing African violets.

Three pots of soil (which had been saturated and allowed to drain) were being sterilized one evening. The oven (Kenmore) was set for 250° F and the soil had been in the oven about 20 minutes. Sterilization was proceeding too slowly so the broiling element was turned on. Upon the application of top heat (soil surface about 3 inches from the heating elements) considerable water started running from the holes in the bottom of the pots. When the broiling element was turned off, the water trickled to a stop. When the element was turned on again the flow started. Now the question; Was the flow related to anything other than temperature effects? Is heat radiation a force which will move water through the soil profile?

Comments of the Vicksburg Research Center on solar radiation and soil moisture depletion were reread. (October 1957 - March 1958 Semi-Annual Report). Their results show that solar radiation is an important factor in soil moisture losses, but nothing is said to indicate it has any effect independent of increasing air and soil temperature (and related effects of these factors). Comments will be welcomed.

SISKIYOU-CASCADE RESEARCH CENTER

--- by H. G. Herring

Tractor Skid Road Erosion (FS-1-w4-2)

This summer we initiated a study of erosion on tractor skid roads, using a combination of successive cross-sectional profile measurements and the double-drum catchment with flow divider described in our last report. To date, 12 plots have been established, each extending the full width of the road and ranging from 65 to 180 feet in length. They are on gradients ranging from 11 percent to 50 percent and are located on soils derived from meta-gabbro and hornblende schists of the older Cascades.

We hoped to get in more plots this season, but were forced to await completion of logging and are about to be cut-off by the start of the rainy season. This emphasizes the desirability of choosing areas that are to be logged early in the season if at all possible. In this case there were no suitable areas available sooner. More plots will be established on newly logged areas next year and we hope to have enough to permit multiple regression analysis, relating soil loss to such variables as length of slope, slope gradient, soil pemeability,

stoniness, and precipitation. The plots will be remeasured each year for three years.

We are installing a flow divider and double-drum catchment on approximately one-third of the plots. These will provide a comparison of the soil removed versus sedimentation methods of erosion measurement. They will also give us an idea of the trap efficiency of a single drum and the relationship of runoff to precipitation.

An interesting sidelight of the experiment is the method developed to measure profiles. Angle-iron stakes were driven into each side of the road, at 20 ft. intervals, and were notched on top with a triangular file. A graduated piano-wire, stretched by a turnbuckle across the bottom of a broad aluminum angle-iron A-frame--in effect, a large bow--was laid across the stakes, in the notches. A plumbed flexible tape was then used to measure the vertical distance between the wire and the ground to establish the profile. This device eliminates any lateral stress on the stakes and minimizes the chance that they will be displaced. The aluminum and wire truss we used was 15 feet across the bottom with 8' aluminum legs and cross brace. It is easily assembled and disassembled for transportation to and from the study area.

Experimental Watersheds

We consider ourselves quite fortunate in locating four and possibly five good watersheds on the South Umpqua Experimental Forest. They are all about 100 acres in size, are untouched and have what appear to be ideal gaging sites. They are contiguous and the gaging sites are all within a half-mile of each other. They also produce perennial streamflow which is not too common for watersheds of that size in this area.

We have also been looking for some suitable watersheds in the high Cascades' Shasta fir type, but the drainages are very poorly defined in that zone and we have about given up hope of finding any. Our intentions are to conduct some coordinated forest management-watershed management studies in that type with the watershed studies aimed primarily at snow management. In view of the lack of suitable watersheds, it appears that our studies will be limited to plot work.

In connection with gaged watershed studies, we are very much interested in improved methods of measuring sediment--both suspended and bed-load. The effect of land use upon sediment production will receive more emphasis in this province than will its effect upon water yields and we doubt that we can measure sediment production with sufficient accuracy. We hope the inter-agency committee on sediment measurement comes up with some new approaches. Does anybody else have some ideas?

WILLAMETTE RESEARCH CENTER

--- by Jack Rothacher

General

"Watershed Management" like "Multiple Use" seems to have become a magic phrase meaning all things to all people. During the past year it has been the theme of many regional meetings. Foresters and the public in general are certainly becoming increasingly aware of the general concept of watershed management. In November the Isaac Walton League will hold its annual convention in Eugene with watershed management as their main topic of discussion. Approximately 150 Waltonians are expected to visit our watersheds on the H.J. Andrews Experimental Forest during their meeting. Their visit will climax a long season of show-me trips. To facilitate handling of visitors a new guide book has been prepared for review and a number of the experiments on the Andrews are being signed.

Small Watershed Studies (FS-1-w5-2; FS-1-w5-3; FS-1-w7-6)

Preparations for the first treatment in our gaged watersheds on the H. J. Andrews Experimental Forest are about to be completed. A sale of 11 million board-feet will be made to the highest bidder on October 16. As a part of the contract the operator will construct approximately 1.7 miles of logging road in experimental watershed #3 (a 250 acre drainage) during the summer of 1959. All construction within the watershed is to be completed by September 30, 1959 so that the full effects of the roads will be measured during the water year 1959. Logging will be delayed for three wet seasons or until the summer of 1962 when approximately 3-million board-feet (25 percent of the drainage) are scheduled for logging. As previously reported, use of accelerated amortization of road costs has made it possible to pay for constructing the roads inside the watershed with timber cut from adjacent areas outside the drainage boundaries. By doing this we can delay logging within the watershed without requiring the purchaser to tie up large sums of money in construction costs for several years.

We have been somewhat apprehensive about reaction of prospective bidders to a delayed cutting schedule. However, the idea has apparently proven quite attractive to the larger operators who like to plan their logging well in advance. For the privilege of working with us on this sale, the purchaser must bid a minimum of $17.95 per MBM for Douglas-fir, $3.15 for western redcedar, and $6.60 for western hemlock and other species.

We now have 5 years of records for the three experimental watersheds which range in size from 149 to 250 acres. With an average annual precipitation of 83.43 inches, runoff has averaged 59.43 inches or approximately 71 percent.

The second year records from the sediment basins on each of the watersheds indicate slightly higher accumulations than the first. This is probably due to the unusually high peak flows of last winter. Averages for the three basins for the two-year period are:

Watershed	Area	Average annual accumulated sediment* for '57/'58	
		Cubic feet/acre	Acre feet/sq. mile
1	237	1.85	0.0272
2	149	2.91	0.0427
3	250	2.69	0.0395
Weighted Average		2.43	0.0357

* Wet volume including incorporated organic matter.

To further probe into the problems of sedimentation resulting from logging, a cooperative project with Oregon State College has been started. Professor Bob Wilson, working on an advanced degree is studying the sources of erosion from roads with an ultimate objective of determining what conditions create significant soil movement. This is a two-year project which we hope will be closely correlated with the roads constructed in watershed #3.

BLUE MOUNTAIN RESEARCH CENTER

--- by Norman Miner

Snow Reconnaissance Study (FS-1-w1-2)

After wallowing through the snow all spring we have come up with some data on snow accumulation and rate of melt for two separate areas in the Blue Mountains. One area -- Anthony Lakes -- is a narrow valley with steep north and south slopes. The second area at Tollgate is more exposed and lacks the sharp variations in topography which characterize Anthony Lakes. It did not take long to find that characteristics of the snow pack were dissimilar as well.

At the end of the snow-melt season we had data on initial accumulation and rate of melt for 50 sampling points in each of the two areas. Sampling points were in the center of natural openings ranging in size upward from 10 feet in diameter. In addition we had a measure of seven "associated" variables for each sampling point. These were:

x_1 Elevation, feet above sea level.

x_2 Slope gradient, percent.

x_3 Aspect, 0^o - 180^o measured from north through east, and west to south.

x_4 Shade, percent inclination from sampling point to average crown wall on south quadrant.

x_5 Shelter, average percent inclination from sampling point to average crown wall on north, west, and east quadrants.

x_6 Average radius of opening in feet.

x_7 Area of opening in square feet.

Data for the two dependent and seven independent variables for the two areas was then processed by the IBM 650 and out of the resulting welter of figures we have so far concluded that the seven variables are associated with snow accumulation at Anthony Lakes and with rate of melt at Tollgate. We have only begun to analyze what the 650 is trying to tell us but at first glance we know that it will be a somewhat garbled story. In other words, we have failed to measure some of the important factors that influence both accumulation and melt.

Scab Ridge Study (FS-1-w1-4)

This summer we installed four runoff plots, each .02 acre, on a grassland slope in the Starkey Experimental Forest and Range. The study site is typical of many acres of so-called scab ridge in the Blue Mountains. Soil is a thin mantle over semi-fractured basalt. Water storage capacity is very low and vegetation is sparse. Snow melt and rainfall move off these areas rapidly. They present a problem of rehabilitation by any available means. Past research has shown that reseeding, mulching and fertilization can effectively increase cover and probably improve water storage capacity.

Our purpose is first to learn some of the characteristics of runoff from areas of this kind. Then we plan to apply various treatments designed to improve the site and to measure their effects on runoff and erosion.

SEMIANNUAL REPORT--April 1, 1958 through September 30, 1958
Division of Watershed Management Research
Rocky Mountain Forest and Range Experiment Station

FLAGSTAFF

Interception of pole-size ponderosa pine

Interception of rainfall has been measured in nine 10th-acre plots of pole-size ponderosa pine with densities of from 48 to 278 square feet basal area per acre on the Coconino National Forest. Regression data and observations indicate that throughfall begins with storms of about 0.05 inch. Stemflow was observed to begin at about 0.20 inch of rain. Covariance analysis showed that the nine individual plot regressions for net rainfall were significantly different among themselves at the 5 percent level. The magnitude of these differences was small. There was no consistent relationship between basal area and the amount of rainfall intercepted. Gross rainfall interception averaged 17 percent.

Litter accumulation

Age and basal area of pole-size ponderosa pine appear to provide a reliable measure of oven-dry litter weight in the Southwest. A multiple regression equation of stand age in years (X_1) and basal area in square feet per acre (X_2) on litter weight in tons (Y) was:

$$Y = 0.301\ X_1 + 0.023\ (X_2) - 7.31$$

The correlation coefficient was 0.935 with significance at the 1 percent level. The confidence interval, with a mean value of 11.8 tons per acre, was $\pm$2.1 tons per acre. This equation accounted for more variation than either age or basal area taken alone. The equation is limited to pole stands between 30-70 years old and 48-278 square feet basal area per acre growing on "good" sites (formal site standards are unavailable). Extremely dry or wet sites were not sampled.

Miscellaneous

Joseph Wichsberg has written a book worthy of the attention of watershed men interested in snow work and/or high adventure. "Avalanche!", 254 pages, New York, Alfred A. Knopf, $4, tells of the two separate avalanches that snuffed out the Austrian village of Blons on January 11, 1954. The book, besides describing the actual tragedy in minute detail, covers the many fascinating and unpredictable facets of avalanches. The knowledge presented in the book is probably "old stuff" for those working with United States avalanches and may have little applicability to United States conditions. Even so, it is still a well documented, highly interesting story.

E. F. Aldon

Disposition of precipitation in the Utah juniper type

Ten experimental plots, stratified according to stand density, were established in the Utah juniper type on the Beaver Creek drainage. Measurements of precipitation, interception, soil moisture, and surface runoff began during April. Total precipitation from April to September 10 was approximately 4 inches. The usual spring dry period extended well into July, only 0.75 inch being recorded from April 21 to July 22. During this period there were 70 consecutive days with no precipitation.

Preliminary data indicate that stemflow begins between 0.25 and 0.30 inch, and that it is not too important as a factor in the disposition of rainfall. Gross interception has varied from 3 to 34 percent of total rainfall, depending on stand density.

Monthly gravimetric samples of soil moisture show that moisture values dropped slowly and rather uniformly-- from an approximate average of 32 percent in April to 20 percent in July. Because of soil-depth variability within the plots, 9 to 52 samples are required to obtain average depth estimates to 1 inch with 95 percent probability ranges.

Surface runoff has been recorded on only two plots to date, largely because of scarcity of large storms. These two plots have the shallowest soils, greatest slopes, least vegetation, and showed no soil cracking.

A survey of the experimental plots showed that soil cracking trapped considerable potential surface runoff. Minimum estimates in terms of inches of water storage capacity are listed below:

Plot number	Water storage capacity as of July 20 (Inches)
1	0.14
2	.13
3	.10
4	.11
5	.02

No cracking was observed on four other plots. Despite approximately 3 inches of rain that fell from July 22 to September 10, the cracks have remained essentially intact. Trench excavations showed typical large cracks to be 2 inches across at the surface, pinching down to 1 inch wide at 24-inch depth in a caliche layer directly above bedrock.

C. M. Skau

Snow accumulation in relation to logging intensity

Exploratory research indicates a possibility of increasing streamflow through logging in mixed ponderosa pine-Douglas-fir stands. During the fall of 1957 a study, patterned from the Fraser study in lodgepole pine, was established to measure the effect of two intensities of logging on snow accumulation. Two blocks, each containing a plot of (1) uncut, (2) selection cut removing approximately 60 percent of merchantable volume, and (3) commercial clear cut down to 10 inches d.b.h., were laid out on north exposures. During the winter, following every storm, 25 snow core samples were taken from each plot.

Preliminary results indicate:

1. A 4 percent increase in water content of the snow pack as a result of selection cutting.

2. A 28 percent increase in the water content of the snow pack as a result of commercial clear cutting.

3. A higher melt rate on the clear-cut plots than on uncut or selection cut plots. (Snow disappeared from all plots at very nearly the same time.)

One more winter's data will be taken on the present study. If similar relations emerge, a pilot study measuring more factors will be designed to determine how much of the increase in the snow pack is made available for streamflow.

Precipitation-runoff relations of a Front Range watershed

Missouri Gulch watershed, 4,600 acres in size, has been under study since 1940. It heads in the ponderosa pine zone and flows westward; elevation ranges from 9,300 feet to 7,500 feet. Portions of the watershed are covered by old-growth stands of timber; but much of the area has been logged and burned. Soils are predominantly gravelly sandy loams, of the Edloe and Stecum series, derived from Pikes Peak granite. Ponderosa pine-Douglas-fir is the dominant vegetation type. As part of a grazing allotment, the watershed receives moderate grazing use by cattle annually.

Climate is mild. Summer temperatures average 55° F., winter temperatures average 25°F. Snows occur from late September through May, but commonly melt from south exposures and valley bottoms within a few days. Snows remain during winter only on north exposures. Average annual precipitation for the period 1940-1957 was 18.21 inches.

Precipitation is sampled by a network of 5 recording and 9 standard rain gages during spring, summer, and fall. Winter

precipitation is measured by 1 recording and 13 standard gages. Equivalent uniform depth distribution of precipitation over the watershed is accomplished by the Thiessen method.

Streamflow is controlled by a 2-foot San Dimas flume installed at the mouth of the watershed. The gage rests upon bedrock and is capable of measuring total outflow. However, this gaging station is subject to severe icing in the winter when flows are low. Ice forms in layers in the flume, often building up to 5 feet thickness during a winter. Consequently, the period of record for this gage is limited to from April 1 to November 1 annually.

During 1951, two 30-inch, 90° V-notch weirs were installed on subwatersheds within Missouri Gulch. The period of automatic record of these gages, due to icing within the still wells, is approximately the same as that of the San Dimas flume. However, turbulence of flow at the notch keeps the notch free of ice all winter, allowing periodic readings to be taken. This essentially extends the period of record to yearlong.

In the analysis it was found that for coincident periods of automatic record the combined flow of the two subwatersheds is closely correlated[1/] with the flow at the flume controlling the entire watershed. From this regression winter flow from the entire watershed is estimated directly from the combined winter months' flow from the tributaries. Table 1 summarizes the estimated total annual flow (sum of measured seasonal and estimated winter flow) of Missouri Gulch watershed for the period 1952-1957.

Table 1.-- Estimated total annual outflows, Missouri Gulch watershed

Year	Total precipitation	Total flow	Precipitation becoming streamflow
	Inches		Percent
1952	15.7	1.1	7.0
1953	18.6	0.9	4.8
1954	12.7	0.5	3.9
1955	16.7	1.1	6.6
1956	14.6	0.5	3.4
1957	26.9	3.7	13.8
Average	17.5	1.3	7.4

From table 1 it can be seen that Missouri Gulch, with its headwaters in the Colorado Front Range ponderosa pine type, is a low water yielding basin. Yields, quickly responsive to precipitation amounts, would be expected to be less than 10 percent of average annual precipitation.

1/Regression line: $y = 0.033 + 0.763x$. This estimate is based on streamflow measurements for 36 months during the period 1951-57. Correlation coefficient 0.998. Standard error of estimate, ± 0.020 inch.

Pressure-sensitive materials tested

Pressure-sensitive paint, manufactured by the Clark Electronics Laboratory of Palm Springs, California, was used in some pressure transducers this past season. The principle of the paint is variable resistance with compression. Electrical resistance of the transducer can be related to the weight resting upon it.

The transducers are part of a type of weighing lysimeter (or phytometer) to be used in a transpiration study. Large garbage cans containing approximately 500 pounds of soil and supporting a number of oat plants were suspended from two transducers. The objective was to relate changes in resistance to water use by the oats. Due to several technical difficulties, a good calibration was not obtained. However, it was demonstrated that the transducers were sensitive to within 100 gram units and offer many possibilities in our work when we learn to use them.

H. W. Berndt

More about the exchange of moisture between an alpine snow surface and the air during summer months

Preliminary results of studies to determine the moisture exchange between an alpine snow surface and the atmosphere were presented in the watershed management semiannual report for fall 1957. These data indicated a gain of moisture from the air. When the tests were repeated at another site in July 1958, a net loss of moisture from the snowfields was recorded. Although the 1958 data are not yet completely analyzed, a few interesting comparisons can be made between the two summer periods.

During 8-1/2 days in early August 1957, moisture exchange between the atmosphere and on alpine snow surface averaged +0.0020 inch per hour. This is equivalent to a gain by the snow of about 1,300 gallons of water per acre of snow per day. During a 9-day period in July 1958, the moisture exchange averaged -0.0024 inch per hour which is equivalent to a loss from the snow of about 1,600 gallons of water per acre of snow per day.

The above data were obtained from plastic-lined pits which were loaded with 150 cubic feet of snow at the beginning of the period and left until all snow had disappeared. Hence, these moisture exchange data are net for the two periods involved. In order to determine diurnal variations in moisture exchange, small plastic pots were also loaded with snow and exposed to the atmosphere. The snow in these units was renewed every morning, noon, and late afternoon.

From the small units it was possible to determine the average rates of moisture exchange by times of day for the two summer periods. These are presented in table 1.

Table 1.-- Diurnal variation in moisture exchange between the atmosphere and on alpine snow surface

August 1957		July 1958	
Time of day	Average moisture exchange in inches/hr.	Time of day	Average moisture exchange in inches/hr.
Late afternoon and overnight	+0.0008	Overnight	+0.0008
Mornings	-0.0036	Mornings	-0.0036
Mornings and early afternoon	-0.0005	Afternoons	-0.0041

It is interesting to note that the major factor contributing to the switch from condensation in August 1957 to evaporation in July 1958 was the ninefold increase in evaporation during the later period. This increase in evaporation reflected the very dry air mass that dominated the area during the July tests. Afternoon winds averaged 11 miles per hour with several periods of more than 20 mph. Dewpoints were in the middle teens or low twenties.

Perhaps the most important thing brought out by these experiments is the magnitude of the evaporation or condensation in relation to the melt water produced by alpine snowfields under summer conditions. In July 1958 evaporation amounted to only 3.1 percent of the total weight of snow available for ablation at the beginning of the test period. In August 1957 condensation amounted to 2.2 percent of the total weight of snow at the start of the test period. Thus, even during very dry and windy summer weather such as occurred in early July 1958, evaporation accounted for only 3 percent of the total ablation of alpine snowfields. On other occasions a moister air mass and the typical afternoon showers such as enccuntered in August 1957 result in a net gain of moisture on the snowfields.

M. Martinelli, Jr.

Fool Creek studies

Although the treatment of Fool Creek watershed was not completed until the fall of 1956, the fact that treatment was 80 percent complete in the fall of 1955 prompts us for preliminary analyses to call 1956 a posttreatment year. Those readers who have "sweat out" a calibration and treatment period will perhaps excuse this unseemly eagerness to get results.

A covariance analysis based on the 12 pretreatment years and the so-called posttreatment years of 1956 and 1957 revealed an average increase of 4.03 area-inches or 240 acre-feet attributable to the timber harvest. Chance variation could have been 1.85 inches, making the odds 20 to 1 that the true effect of the harvest lies between 5.88 and 2.18 inches.

If we take as the true value the most probable figure of 4.03 inches, the magnitude is surprising when we note that only 278 acres or 39 percent of the watershed was cleared of timber. If the entire increase is ascribed to the area cleared, the increase from this area amounts to 67 percent of the average predicted yield for 1956 and 1957 or to 80 percent of the average pretreatment yield. Such an increase cannot be explained from the knowledge of snow interception gained from earlier studies on plots. We would have to assume that the timber harvest effect spreads beyond the boundaries of the cleared strips and/or that the evapo-transpiration of soil moisture has been appreciably reduced by the timber harvest.

Instrumentation

In searching for an inexpensive totalizer of solar radiation, this reporter has become interested in the Livingston atmometer and other versions and has been impressed with the reawakened interest in its use in hydrologic studies. It is apparently coming back into vogue after years of being old fashioned.

A new wrinkle in atmometer use has been learned from a Canadian scientist who uses atmometers in below-freezing weather as well as in warmer periods. He uses a so-called azeotropic mixture of hydrochloric acid and water to make measurements possible during cold weather and prevent freezing damage to the atmometers. This mixture contains 506 parts of 37 percent HCl to 494 parts of distilled water. As with all azeotropic mixtures, these proportions of HCl and water remain constant regardless of rates or amounts of evaporation while depressing the freezing point sufficiently for the purposes of the Canadian study. The evaporation rate has been found to be about 44 percent of that of distilled water. More information can be given to anyone interested in atmometer use. Incidentally, the HCl should prevent the growth of algae on the atmometer surface-- an important difficulty when only distilled water is used.

Speaking of instruments: Besides an inexpensive integrating radiometer, two other instruments needed for snow research are a portable albedometer and a recording hygrometer accurate at low temperatures-- also reasonably priced. A similarly priced medal is hereby offered to the first person submitting a tested model.

B. C. Goodell

GRAND JUNCTION

Black Mesa watershed studies

On Black Mesa we are studying the relationship between plant and ground cover and the production of runoff and sediment. From this relationship we hope to learn how to predict certain runoff and sedimentation characteristics from measurements of plant and ground cover on a watershed.

Here are the conditions in 1957, at the beginning of the study.

Plant and ground cover on grasslands (based on 3-step transects)

	Watershed		
	4	5	6
	Percent		
Plant density index	26	22	19
Litter	28	38	39
Bare soil	40	38	41
Rock	6	2	1

Suspended sediment during snowmelt

	Parts per million		
Least	5	107	19
Most	765	1,830	1,183
Average	154	383	139

Runoff during snowmelt

	Cu.ft.per second per sq. mile		
Peak discharge	27	36	29

Plant and ground cover will be changed during the study by different intensities of cattle grazing, with watershed 4 receiving light grazing, 5 heavy grazing, and 6 moderate grazing.

The experimental area is at an elevation of about 9,800 feet and has a cover of grassland, aspen, and spruce.

Water use study

Our water use study on Black Mesa, now in its third year, is beginning to show a fairly consistent pattern. We want to find out how much water is being used by aspen, spruce, and grassland during the period between June - October. To date our findings are as follows:

Year	Inches of water used 1/				
	Aspen	Spruce	Idaho fescue	Thurber fescue	Mixed grass-weed
1955	20.94	15.30	10.14	9.86	-
1957	17.14	13.70	-	-	9.34

1/ Based on sites where moisture content was at or above wilting point both spring and fall. Gravimetric sampling is being used.

H. E. Brown

The Black Hills have experienced alternate periods of above-normal precipitation and drought during the past growing season. Precipitation at Rapid City was more than twice average in April, only one-third of average in May, equalled the average in June, was twice the average in July, and was only about one-third of average in August. To date September has also been unusually dry. Precipitation from April 1 through August has totalled 14.06 inches as compared to a long-time average of 12.57 inches for the period. Temperatures ranged from about normal early in the period to below normal in July but have been above normal nearly all of the time since about August 1. Although spring and summer precipitation exceeded average, streamflow has receded to an unusually low point because of the distribution of precipitation. Most spring precipitation through April usually goes into soil moisture recharge and May precipitation provides the bulk of water that goes into streamflow.

Most of the precipitation falling in June and the remainder of the summer goes to evaporation and transpiration. This year April was a good month for soil moisture recharge but below-normal precipitation in May apparently contributed little to runoff. Peak seasonal streamflow, which normally occurs in May, was unusually low and by now some streams have dried up--for the first time in several years and in spite of above-average total precipitation for the April-September period.

Soil moisture

Instrumentation for a study of soil moisture under thinned and unthinned ponderosa pine was completed in June with installation of surface runoff plots. By then the complete network of rain gages, stemflow gages, and Colman soil moisture units were in operation.

Three treatments in the study include clear-cut, thinned, and unthinned pine.

The study is located in a second-growth pine stand 65 to 70 years old. Prior to cutting on the thinned area there were 1,972 trees per acre averaging 3.9 inches d.b.h., and basal area was 164 square feet per acre. Thinning to 10-foot spacing reduced the number of trees to 435 per acre. Average d.b.h. is 5.8 inches and basal area is 80 square feet per acre. There are 2,885 trees per acre on the unthinned area with an average d.b.h. of 3.3 inches and basal area is 171 square feet per acre. All trees were removed from the clear-cut area and in addition the area has been sprayed to prevent growth of herbaceous and shrub vegetation.

Cutting on the cleared and thinned areas was done in August 1957. In December, when soil moisture units were installed there was more moisture throughout the soil profile in the clear-cut area than in either the thinned or unthinned areas. The first indication of moisture penetration to a depth of 3 inches in the

clear-cut area came about the middle of March, according to Colman meter readings, and some moisture had penetrated to a depth of 6 feet by about April 21. Moisture at 6 feet then built up slightly over the next 5 weeks. There has been little change at 6 feet since about June 1.

In the thinned area first indication of increase in soil moisture at 3 inches came between March 17 and 24. Penetration was much slower than in the clear-cut area with no moisture reaching 6 feet until near the middle of July, and then the amounts were relatively small.

Moisture first penetrated to 3 inches and 12 inches in the unthinned area about the same time that it did in the thinned area. But penetration to 24 inches in the unthinned area lagged about 2 weeks behind the thinned area. The lag was almost a month at 36 inches. There was only a slight indication of increase in moisture content at 48 inches in the unthinned area and apparently no moisture at all penetrated to 60 or 72 inches.

By September 15 virtually no available moisture remained in the upper 6 feet of soil in the unthinned area. Moisture unit resistance readings were very high throughout the profile.

Most of the available soil moisture has apparently been removed from the upper 3 feet of soil in the thinned area. At 4 feet, resistance readings on September 15 were little higher than at the minimum point, indicating little moisture withdrawal from this depth, and at 5 and 6 feet there has been virtually no increase in resistance above the minimum point.

Except for slight fluctuations at 3 inches depth there has been little change in moisture content of the entire soil profile on the clear-cut area since it reached maximum moisture content.

These observations from Colman meter readings are, in general, borne out by gravimetric soil moisture samples.

Moisture content measurements (P_w) from gravimetric sampling will be converted to inches of water upon analysis of bulk density, field capacities, and 15 atmosphere moisture content determinations. The picture of distribution of precipitation will be completed with analysis of throughfall precipitation, stemflow, and surface runoff. Field measurements will continue into the fall of 1959.

Several simple pieces of equipment used in this study will be described in the next report.

Runoff characteristics and trends

An analysis of precipitation and streamflow characteristics in the Black Hills has been completed. The Black Hills are basically

a low water yielding area partly because of relatively low precipitation over much of the area and partly because of the seasonal distribution of precipitation. Average annual precipitation is little over 18 inches in a considerable part of the area. In this same area up to 75 percent of precipitation falls during the growing season. Evapo-transpiration potential exceeds precipitation in June and throughout the summer. The small amount of precipitation during the remainder of the year is rarely more than enough to satisfy soil moisture recharge requirements. Hence most streams are intermittent.

Annual precipitation ranges from 18 to nearly 28 inches in the northern and higher Black Hills. Average annual precipitation is 21.46 inches over the upper 332 square miles of Rapid Creek, the second largest watershed in the Black Hills area. Runoff averaged 3.06 inches per year for the period 1915 through 1942, a yield of only 14 percent. In February both precipitation and streamflow start to rise from the winter low. Both increase steadily, runoff to a maximum in May, precipitation to a maximum in June. Streamflow recession in June is believed due to rapid increases in evaporation and transpiration during the month. Precipitation during the remainder of the summer is seldom more than enough to satisfy evaporation and transpiration and therefore makes little direct contribution to streamflow.

Total annual runoff in Rapid City is highly correlated with May precipitation alone ($r = 0.599$). However, an additional significant portion of runoff is accounted for by precipitation during the remainder of the calendar year. The coefficient for correlation of total calendar year precipitation with total calendar year runoff is 0.713.

Nearly 50 percent of the variation in Rapid Creek runoff remained unexplained. It was found that precipitation in the preceding fall months has a significant bearing on runoff in the current year. Precipitation during these months apparently contributes significantly to soil moisture recharge. Runoff in the current year increases with amount of antecedent fall precipitation. The coefficient for multiple correlation of current year precipitation and antecedent fall precipitation with current year runoff is 0.835. Antecedent fall precipitation accounts for an additional 19 percent of the variation in current year runoff.

A multiple regression equation was developed and used to estimate yearly runoff for the period 1915 through 1942; estimated runoff was subtracted from actual runoff. The trend of the residuals in time shows that there was a highly significant decline in runoff per unit of precipitation.

This is the fact but reasons are obscure. It may be due to some long-term carryover effect of ground water storage. This does

not seem very likely, however, because physiographic and geologic characteristics appear to favor rapid drain out of ground water.

Many people particularly interested in water supply of the area believe that water yield has declined and that it has been due to increasing extent and density of second-growth ponderosa pine under management and fire protection. Maybe this is the reason for declining streamflow. The study of soil moisture under thinned and unthinned pine may give us a clue.

H. K. Orr

TEMPE

Pine-Fir Project

New work in pine-fir areas of Arizona

New watershed work has been initiated in the pine-fir type of Arizona. Two watersheds have been selected near Hannagan Meadows at about 9,000 feet elevation by the National Forest Administration and the station. Weirs were built by the Apache National Forest. Instruments were installed July 29, 1958. The objective of this study is to test the effect of some form of timber harvest (to be determined from plot studies during calibration of the watersheds) on water and sediment yields.

A preliminary soil moisture study has been initiated in the area around Big Lake at an elevation of about 9,300 feet. The objective of this soil moisture study will be to determine comparative soil moisture uses and accretions under grass, mixed conifer, and aspen. These types grow close together and under similar environmental conditions. Management toward any of these types seems possible at least over limited areas. Consequently, soil moisture uses by the different types is an important consideration.

North Fork of Workman Creek type conversion

Treatment of the moist-site, fir portion of this watershed was started September 2, 1958. The plan of operations is as follows: (a) Sever all vegetation, including snags, that is 3-1/2 feet in height and over; (b) remove all vegetation that will make a log 12 inches in diameter from the watershed; (c) pile remaining live and dead material in a manner suitable for burning during low fire danger weather; (d) reseed cleared area to a mixture of perennial grass; (e) control pine reproduction and hardwood sprouts on seeded area at intervals as needed.

Clearing and piling should be completed by October 15, 1958. Burning is planned for the fall. Reseeding will be done immediately after burning and again in June 1959 if necessary to establish a satisfactory stand of grass.

Rainfall and runoff from the Salt River watershed

The first stream gaging station for determining discharge on a continuing basis in the Colorado River Basin was placed in operation on Salt River in August 1888. Analysis of the records for the Salt and Verde Rivers and Tonto Creek since that time indicates that streamflow is strongly related to precipitation in spite of deviations for individual years. These deviations may be due to (1) unusual rainfall distribution, (2) inadequate precipitation sample, (3) watershed changes, and (4) carryover effects from previous years. Double-mass analysis was used to detect relations. A plotting of annual streamflow against precipitation shows about as many years from the early and the recent part of the record on each side of the average line. This indicates little change in the proportion of precipitation that reached the stream. Double-mass plotting of precipitation against streamflow shows changes at points of increased and decreased streamflow suggesting carryover effects. Annual streamflows plotted double-mass against a control, calculated from precipitation and low autumn streamflow, show some effects of high and low years but no continuous trends. Precipitation and carryover effects seem to have been dominant causes of streamflow changes. Alteration of watershed conditions appears to have had little effect.

L. R. Rich

Phreatophyte Project

Comparative evapo-transpiration from tamarisk and Bermuda grass

The field apparatus for studying evapo-transpiration is now operating successfully. Transpiration of tamarisk (*Tamarix pentandra*) and Bermuda grass (*Cynodon dactylon*) are being studied along the Salt River. In the tests, adjacent tents are erected over a tamarisk shrub and over Bermuda grass. These tents are without supports and are inflated like a balloon by the air blower. The infrared gas analyzer measures humidity of the air blown into and escaping from the tent. The increase of air moisture in the escape air indicates the evapo-transpiration of the enclosed vegetation plus the surface area covered by the tent. Readings are alternated between the two tents to arrive at comparative rates.

A 9-foot tall tamarisk growing in a site with shallow water table and surrounded by Bermuda grass was losing water at a rate of 100 gm.per minute. The comparison tent placed over Bermuda grass gave 38 gm.per minute. A series of four tests comparing Bermuda grass and an open pit of water gave an average water loss of 66 grams per minute for grass and 54 grams for the open water.

J. P. Decker

Ecological studies

Results of seed germination studies of phreatophyte species follow closely the information obtained during 1957. Tamarisk seed lose their viability in 4 to 6 weeks if stored in summer outdoor temperatures and in 6 to 10 weeks if stored at room temperatures, but may retain some viability up to a year if stored at 40° F. Seepwillow (Baccharis glutinosa) seeds hold their viability much longer. Cottonwood (Populus fremonti) seeds are short-lived. Arrowweed (Pluchea sericea) seeds have a very low germination capacity.

Stem and root cuttings of tamarisk sprout vigorously regardless of size or position in the shrub. Sprouting is most vigorous in the spring . Root cuttings produced roots but in no cases did they produce stems. Moreover, severed roots rarely sprout.

Tamarisk seedlings grown in pots in the greenhouse developed slowly for the first 6 weeks, then growth accelerated rapidly. Nine clay pots were sown with seed on June 12, 1958. These were thinned to 15 plants per pot upon germination and in 5 weeks they were further reduced to 5 plants. When 2 weeks old, and weekly thereafter, a pot was chosen at random, the shoot growth measured, and the soil carefully removed for root measurement. Weekly growth was as follows:

Age (weeks)	2	3	4	5	6	7	8	9	10
Shoot length (cm.)	0.5	1.2	1.9	3.2	6.6	7.9	11.9	10.7	21.8
Root length (cm.)	1.5	2.8	4.0	5.1	6.3	10.2	15.6	1/	1/

1/ Roots too entangled to measure accurately.

A short article "Inflorescence Development of Tamarix pentandra Pallas" by J. S. Horton, published in the October 1957 Southwestern Naturalist, was issued in June 1958.

J. S. Horton

Root excavations of mature plants

Entire root systems of mature plants are being hydraulically excavated. Tamarisk shows wide diversity in the adaptability of its root system. At one site where the water table was 10 feet, a taproot was developed. Another site with a shallow water table showed a definite lateral type root system. Roots of tamarisk even appear to be adapted for growing in free water.

Arrowweed develops a lateral type root system with many buds. These buds eventually develop into aboveground stems. Thus, many aboveground stems have a common root system. Arrowweed is also adaptable to different water table levels. Plants grow from river level up to 20 feet above the water table. Specially adapted roots permit plants to survive when the water is near the surface.

Seepwillow developed a taproot under all cases studied. None of the excavated plants had roots penetrating soil saturated by ground water. Taproots did, however, extend well into the capillary fringe. Adventitious roots were profuse along the upper portion of the taproot.

H. L. Gary

Chaparral Project

Basic studies of factors influencing water disposition in the 5-1/2 million acre broad-leaved sclerophyll type (chaparral) are being planned under the expanded chaparral watersheds project. Preliminary observations of vegetation and soils representative of the type indicate that exposure (hence radiation) should be investigated especially with respect to evapo-transpiration; and that establishment of "erosion norms" for various soils and slopes should have high priority. Broad objectives of the new project are: (1) an evaluation of hydrological relations of the type in relation to present and manipulated vegetation, and (2) the assessment of effects of altering the vegetation upon livestock and game use, recreation, and other land values.

Studies proposed for early initiation include: (1) phenology of major plant species as related to duration and magnitude of water use, (2) survey of soil types and extent on experimental watersheds, with regard to depth, water-holding capacity, and erodibility, and (3) use of water by scrub oak as related to exposure.

Controlled burning in medium density chaparral

A study of controlled burning of chaparral under prescribed, noncritical burning conditions (ordinarily these stands burn only in high hazard periods) is being initiated near Prescott, Arizona, in cooperation with the Prescott National Forest. Major objectives are to obtain some preliminary guides to the use of fire in the type, and to observe morphological and ecological responses of 4 primary shrub species to burning during different seasons. Shrub crown density and herbaceous ground cover have been measured on 5 systematically located 10 x 10 ft. sample plots in each treatment subplot. Total shrub crown cover varies from 34 to 50 percent. Specific plant responses are to be recorded on individually tagged plants, where maximum temperatures obtained will be recorded by use of Tempilaq on aluminum plates. Four 2 chain x 2 chain replicates for each of the three brush treatments are contained within each 4 x 12 chain "season" block, which will be burned as a unit. Area ignition technique will be employed at 4 seasons on "unsmashed," "50 percent smashed," and "100 percent smashed" brush. Fire data measurements, including antecedent records of fuel moisture, air temperature, humidity, and precipitation, have been in progress since May, at which time the brush was smashed. First seasonal burn is scheduled for late September 1958, others for November 1958, and February and early May 1959. Time of actual burning will depend

on weather and fuel moisture, since burning will be attempted only within prescribed fire danger limits as determined by use of the Region 3 "two-index" meter.

G. E. Glendening

Recovery of chaparral vegetation in central Arizona following fire

Remeasurement of permanent transects shows that rapid recovery of chaparral shrubs has followed the large, hot, wild fire of June 1956 on Mingus Mountain. Turbinella oak, a vigorous sprouter, heads the list for rate of recovery, and will soon attain its original density. An interesting feature is the present very low density of perennial grasses, even including the reseeded Eragrostis curvula. While grasses probably had a low density before the fire, they have shown little tendency to increase since the nearly complete removal of the brush canopy. The following table shows ground cover changes in grasses and shrubs to date:

Mingus Mountain Burn
Ground Cover-Percent

Species	June 1956	Fall 1956	Fall 1957
GRASSES			
Native	0	0.11	0.29
Reseeded	0	.01	.01
Total grasses	0	.12	.30
SHRUBS			
Quercus turbinella	0	4.35	12.84
Rhus trilobata	0	.61	1.14
Mimosa biuncifera	0	.31	.44
Cercocarpus montanus	0	.02	.23
Mahonia repens	0	.02	.13
Garrya wrightii	0	.00	.13
Rhamnus crocea	0	.00	.05
Other	0	.07	.13
Total shrubs	0	5.38	15.09

Cooperative watershed-game investigations on 3-Bar wildlife area

Vegetation mapping and sampling were virtually completed on the four 3-Bar watersheds in September 1958. Twenty randomly located, permanent, double-belt transects, each 1 ft. x 100 ft. and 10 ft. x 100 ft., were established in the mixed chaparral type on each watershed. Crown cover of all shrubs and basal cover of herbaceous plants were recorded on the 1 ft. x 100 ft. belt. Crown cover of six important shrubs only was measured on the 10 ft. x 100 ft. belts.

Where line as well as belt transects were run, analysis shows that the belts give the same level of accuracy with from 24 to 74 percent savings in time. Re-readings by a single observer and readings by a second man were at least as reliable with the belt transects as with the lines. The great variability within the type makes line transects inefficient. Even with belt transects a prohibitive number of samples is required to sample individual species to a standard error of ± 10 percent at the 95 percent confidence level. For example, for the third most abundant species, 88 belt transects are required; for the seventh most abundant species 452 transects. From 31 to 286 percent more line transects would be required for the same level of accuracy.

Sampling is time consuming for a reasonable degree of accuracy because of the low densities of a number of shrub species. Two species--Quercus turbinella and Cercocarpus betuloides-- dominate, occupying more than 10 percent of the ground cover. Densities of the next five most abundant shrubs range from 0.8 to 4.0 percent. Unfortunately, the browse species most important to game and livestock fall in the low density group. Because of difficult terrain and high shrub density, only two to three belt transects can be established and read per man-day.

C. P. Pase

New experimental watersheds near Prescott

Five new experimental watersheds, located in two clusters, are now in operation on the Prescott National Forest. These watersheds vary from about 50 to 300 acres in size, elevations range from 6,000 to 7,000 feet, and reported rainfall averages about 18 to 20 inches.

Extreme fluctuations are expected in streamflow. Accordingly, each gaging installation was designed with 1.0 ft. high 120° V-notch weirs for low flow operating in series with a San Dimas flume for the higher discharges. Prefabricated metal flumes are being used. Both the flumes and weirs are set in gravity section concrete abutment walls.

Summer storms of up to 1/2 inch measured precipitation with intermittent dry spells did not produce noticeable flow in the stream channels. Rains of about 1 inch (intensities not known) have produced streamflow. Both summer and winter flows have now been observed in all the sample watersheds. A measured rain of nearly 1-3/4 inches over one 50-acre watershed brought more than 20 cubic yards of debris into the weir pond. Such occurrences point out the need for devising better ways and means of measuring sediment contributed from areas known to produce extreme fluctuations in streamflow.

P. A. Ingebo

SEMIANNUAL REPORT

Division of Watershed Management Research
Southeastern Forest Experiment Station

April 1, 1958 - September 30, 1958

COWEETA HYDROLOGIC LABORATORY

Annual versus Semiannual Reports

We agree with Herb Storey that the value of By Their Fruits . . is mainly in the opportunity for free discussion of ideas, methods, and techniques. It provides each of our workers with the chance to get the benefit of reactions and the experience of all our people in watershed management research at a time when these reactions and comments are still profitable. Formal reports and publications should benefit from this prior exchange of views. Researchers would be better able to determine beforehand which of their results and theories need the most careful handling in the light of potential controversy. If reports were issued annually, exchange on a topic might occupy several years, and personal contacts or discussions at meetings in the meantime would render By Their Fruits . . obsolete before it appeared.

Electronic Computing of Streamflow Data

We are in the process of arranging for a trial run of electronic computation of streamflow records. The programming for the machine will be set up for use with 90 and 120-degree V-notch, rectangular and Cippoletti weirs. A trial is being run on one 90-degree V-notch for one year's record. Data have been tabulated from original charts showing corrected stage and clock time. Time intervals are varied to secure adequate delineation of the hydrograph by a series of broken lines. Maximum length of the time interval will be determined by experience. The data will be key-punched and verified electronically. The sample test will be used to develop a cost estimate for the initial processing and the electronic computations. The work is being done in cooperation with Jerry Klutter at Duke University. Besides the possibility of savings in cost, the advantages would be increased accuracy and the availability of card-punched records for a variety of analyses.

Water Yield from Hardwood Forest versus Grass Watershed (FS-1-w1-6-SE)

We have begun the conversion of Watershed No. 6, a 22-acre watershed, from native hardwood cover to grass. Clearing operations have been under way during the past summer. Grass planting will be started in the spring. Problems associated with cultivation and seeding these steep mountain slopes have not yet been entirely solved, but it is expected that the conversion will be completed by 1960.

Visitors

There were about 420 visitors to Coweeta during the past six months, including 175 university students, 30 foreign visitors, and 215 other foresters, technicians, civic groups, etc. Visitors of particular note were: Dr. McArdle, showing Dr. Mann, Chief of the German Forest Service, through the Southeast; Herbert Storey, Marvin Hoover, Charlie Hursh, Howard Lull, Sartz, and Reinhart. Technical groups visiting were R-8 Engineers, Deans of Forestry Schools in Region 8, the North Carolina Section of the Society of American Foresters, and the Hydraulics Section of the American Society of Civil Engineers.

Meetings

Whelan and Hewlett attended the May meeting of AGU in Washington, D. C.; Whelan, the June meeting of the Interagency Work Group Committee on Strip Mining Research in Kentucky; Whelan the R-8 Engineers meeting at Clemson University in April; Whelan, the August meeting of the ASCE Hydraulics Section in Atlanta; and Whelan, the Fire Behaviour Training School in Atlanta.

Publications

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Discussion:

More on Gravimetric Sampling for Soil Moisture (By John D. Hewlett)

In one of the recent issues, we discussed some of our troubles in trying to apply soil moisture data obtained by gravimetric methods to watershed research problems, particularly evapotranspiration losses under various cover types. We have made some progress in clarifying various sources of error which are compounded in collecting, processing, and computing soil moisture values in volumetric units. It is believed that the following statistical methods, developed with the help of T. C. Evans, Station Statistician, are fundamental to the methods variously described by Broadfoot, Hoover, Metz, Lull and Reinhart, using Veihmeyer tubes and various kinds of bulk density samplers. A scheme for optimum allocation of sample numbers is suggested, believed to be particularly useful in forest soils where there is an increase in bulk density with increasing depth below the surface.

In the gravmietric method as customarily used, percent soil moisture by weight of oven-dry soil (Pw) is converted to percent by volume:

$$\bar{P}v = \bar{D}\,\bar{P}w \qquad (1)$$

where $\bar{D}$ is mean bulk density and $\bar{P}v$ is mean percent by volume. Conversion to inches is simple:

$$\bar{I} = \frac{\bar{P}v\ d_i}{100} = \bar{D}\,\frac{\bar{P}w}{100}\,d_i$$

where d_i is the depth in inches of the horizon being studied or sampled. It is convenient to make this discussion in terms of Pv rather than in inches, because the selection of the sampling depth is an arbitrary matter depending on study objectives.

It has often been overlooked that two variables are being sampled in this process, and that the accuracy of an estimated volume of soil moisture depends on the compounded variance from two sources. Statistical procedures provide a method for calculating the variance of a product of two variables:

$$S^2_{\bar{P}v} = \bar{D}^2\,S^2_{\bar{P}w} + \bar{P}w^2\,S^2_{\bar{D}} + 2\ \text{covariance} \qquad (2)$$

where S^2 indicates variance, and the bar ($\bar{\ }$) denotes a mean value.

The covariance term offers some trouble, because Pw and D are correlated when measured simultaneously on samples from a soil horizon under a more-or-less stable moisture regime. In other words, Pw increases as D decreases, other influences being equal. However, these influences, among them, soil texture differences, root patterns, infiltration variations from place to place, cause Pw and D to vary somewhat independently. The correlation will have a negligible effect in equation 2 unless it is very consistent. Measurements at Coweeta on samples obtained with the Lutz undisturbed soil sampler indicated a correlation r = about .75, and covariance analysis seemed to show negligible contribution of the covariance term in equation 2. I have omitted the term in the following discussion, but would be interested if anyone has data which show a correlation $r > .90$.

Equation 2 has interesting possibilities. If any experience data are available, they provide an excellent guide to the number of samples needed to show significance in an effect being tested, as well as for the optimum allocation of D and Pw samples to the various horizons. Many studies have been made in which the sampling for Pw and D was out of balance, and time spent sampling Pw would have yielded more information if spent sampling D, or vice versa. The effect of a proper distribution of samples is to minimize the variance for any given total number of samples of both D and Pw = (N).

As an example, suppose the upper six inches of a forest soil is to be sampled periodically for moisture depletion and accretion. It is known from experience that D will be around 0.75, and will have a standard deviation of 0.12 (variance = 0.0144). Moisture will vary from 35 to 55 percent, averaging 45 percent over the period to be sampled. Standard deviation of Pw is about 6 percent (variance = 36). An arbitrary sampling design calls for 5 D and 10 Pw samples, under the assumption that Pw is the most variable factor. Variance is calculated around the average moisture level 45 percent, as shown in equation 2. Variance of percent moisture by volume is 7.88.

By improving the sample combination we can reduce the total number of samples, N, necessary to give this accuracy. The following expression is derived from equation 2:

$$\frac{n_{Pw}}{N} = \frac{\bar{D}\ S_{Pw}}{\bar{D}\ S_{Pw} + \bar{Pw}\ S_D} \qquad (3)$$

Where: n_{Pw} is the number of Pw samples.

N is equal to $n_{Pw} + n_D$, or the total number of samples.

S denotes standard deviation wherever used.

Using this equation in the example, it can be shown that the expected variance is no greater for 7 D and 5 Pw samples than for 5 D and 10 Pw samples. Furthermore, the optimum combination of samples (that which will give the lowest variance for any total number N) is 45 percent Pw samples and 55 percent D samples.

It may be objected that it is easier to sample Pw than D. However, if a series of soil moisture measurements through time is planned, this may not be true. In any case, equation 3 may be altered to include cost factors where experience has made these available, and when full details of the study plan are known.

There remains the problem of determining the total number of samples (N) necessary to hold variance within any chosen limit. Equation 4 has been derived mathematically from equation 2:

$$\sqrt{N} = \frac{\bar{D}\ S_{Pw} + \bar{Pw}\ S_{D}}{S_{Pv}} \qquad (4)$$

The following table contains experience data for Coweeta soils, based on thousands of samples secured under various studies, using plots between 33 and 50 feet square.

Depth (inches)	Mean D	$\bar{S}_D$	Mean Moisture* Level (Pw)	$\bar{S}_{Pw}$
0 - 6	0.90	0.12	35	4.74
6 - 12	1.00	0.12	29	4.25
12 - 24	1.15	0.12	26	3.58
24 - 36	1.25	0.12	22	3.50
36 - 48	1.30	0.12	20	3.53
48 - 60	1.35	0.12	20	3.53
60 - 72	1.40	0.12	19	3.37
72 - 84	1.45	0.12	17	3.16

Mean D values are curved from many data on file, as are the mean moisture levels. Standard deviations are derived from about 10,000 Pw and 400 D samples from 17 widely scattered plots. No significant difference exists between depths in bulk density variance (at least so far as these data

*"Mean moisture level" is one of several soil moisture equilibrium conditions which might be used. In this case, it indicates the average field moisture percentage over 2 years time.

indicate), but moisture variance is definitely related to depth. Mean moisture levels reflect an inverse relation with bulk density.

Conditions found in any particular plot will of course deviate from these rough means. In the absence of any other information, however, these data enable the experimenter to establish a basic plan for soil moisture studies. Using equations 2, 3, and 4, the following values are calculated, from which the curves in Fig. 1 are plotted.

Depth	$\bar{D}\, S_{Pw}$* / $\bar{P}w\, S_D$	N (Total number of samples) for expected S_{Pv} = 0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
0 - 6	8.40	282	70	31	18	11	7.8	4.4	2.8	2.0
6 -12	7.65	234	59	26	15	9	6.5	3.7	2.3	1.6
12-24	7.23	209	52	23	13	8	5.8	3.3	2.1	1.5
24-36	6.99	196	49	22	12	7.8	5.4	3.1	2.0	1.4
36-48	6.93	192	48	21	12	7.7	5.3	3.0	1.9	1.3
48-60	7.10	202	51	22	13	8.1	5.6	3.2	2.0	1.4
60-72	7.02	197	49	22	12	7.9	5.3	3.1	2.0	1.4
72-84	6.66	176	44	20	11	7.1	4.9	2.8	1.8	1.2

*See Equation 4.

Depth	Ratio* n_{Pw}/N	n_{Pw} (Number of Pw samples) for expected S_{Pv} = 0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
0 - 6	.504	142	35	15.6	9.1	5.5	3.9	2.2	1.4	1.0
6 -12	.549	128	32	14.3	8.2	4.9	3.6	2.0	1.3	0.9
12-24	.573	120	30	13.1	7.4	4.6	3.3	1.9	1.2	0.9
24-36	.626	123	31	13.8	7.5	4.9	3.4	1.9	1.3	0.9
36-48	.657	126	32	13.8	7.9	5.1	3.5	2.0	1.2	0.9
48-60	.665	134	34	14.6	8.6	5.4	3.7	2.1	1.3	0.9
60-72	.678	134	33	14.9	8.1	5.4	3.6	2.1	1.4	0.9
72-84	.697	123	31	13.9	7.7	4.9	3.4	2.0	1.3	0.8
0 - 84 (Mean)		129	32	14.3	8.1	5.1	3.6	2.0	1.3	0.9

*See Equation 3.

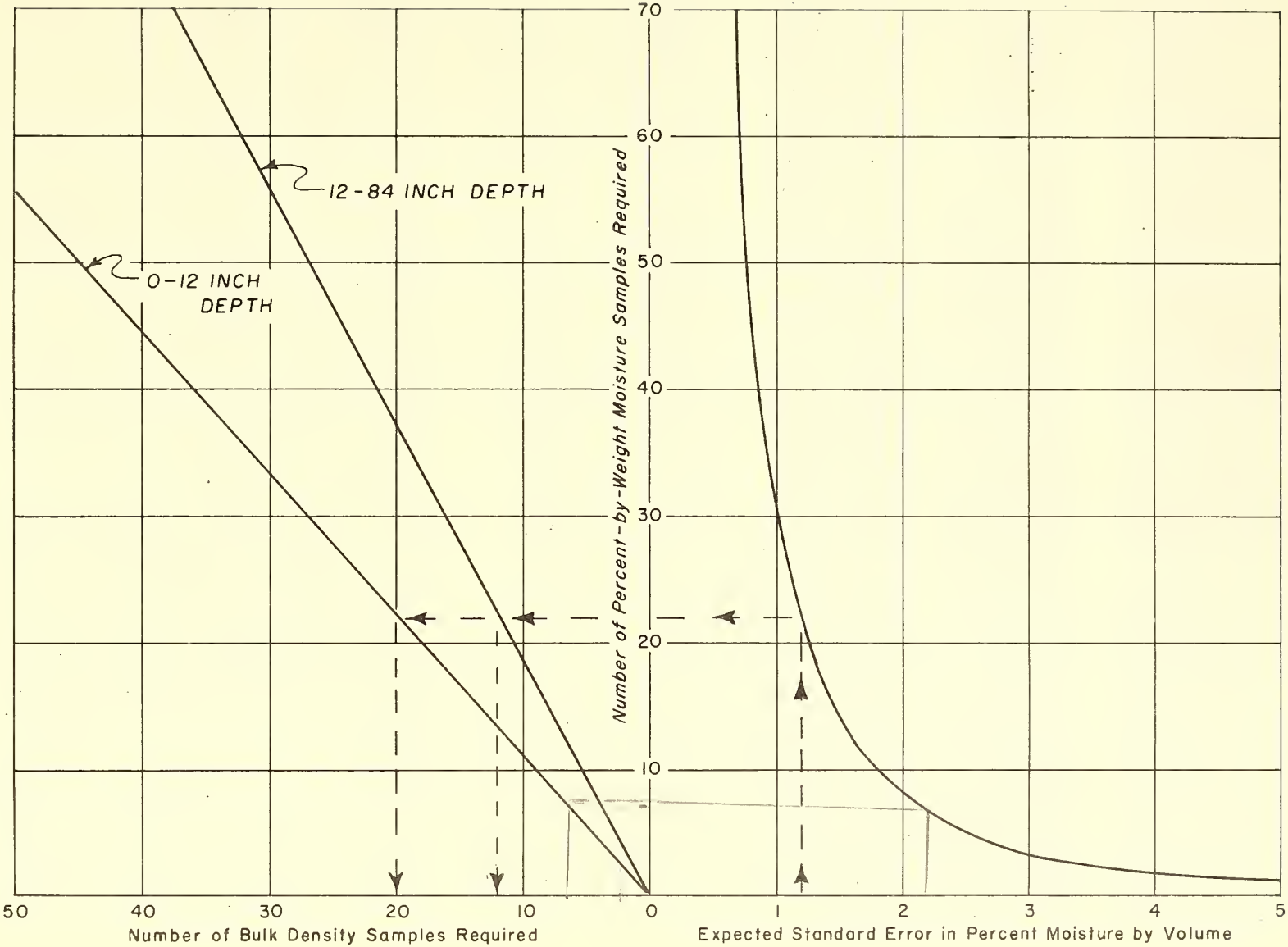

Figure 1. -- Sample numbers required for given Standard Error (at Coweeta).

The total number of samples minus the number of Pw samples ($N - n_{Pw}$) gives the number of D samples necessary to complete the sampling plan. It can be seen that the number of Pw samples required is relatively constant for all depths, but that the total number (N) is considerably larger in the top foot. Thus the required number of samples for bulk density is plotted as two curves in Fig. 1, more samples being required in the top foot of soil than in the lower depths.

Compromises can be made in the use of the curve for design purposes. If soil factors affecting moisture variability are less variable than average in the plot selected for study, the curve is conservative; if more variable, the curve is optimistic. From a curve of this type, a lot of information is available about the feasibility of proposed study plans.

At Coweeta, it is shown by the curve that from 1 to 10 samples of Pw consist in an uneconomical sampling plan; somewhere from 10 to 20 are perhaps optimum; 20 to 30 are maximum; and over 30 samples extremely impractical. In a study designed to show differences in water use by various cover types (currently we are interested in forest and grass), it would be an unusual season in which we could show by gravimetric sampling a trend in water use under either cover, let alone differences.

Suppose we have two plots, one under grass and one under forest, and the actual depletion of soil moisture is .13 and .18 inch per day, respectively. We sample on the 1st of July, and again on July 30th. Ruling out rainfall complications (which we might do in one year out of five), respective moisture losses would be 3.9" and 5.4", a difference of 1.5" between forest and grass. On these two plots, according to estimated confidence units, a total of 120 samples of Pw alone would be required to show a standard error of difference of $\pm$ 2.0". Even with this number of samples, little information would have been gained.

It is recognized that such examples do not cover all the possibilities and that these data do not prove that gravimetric sampling is of no value, but they do illustrate some of the serious difficulties which will be encountered if soil moisture variation is underestimated or ignored. We invite direct correspondence on these techniques or the mathematic deviations.

Under the theory that no chance should be overlooked in the search for alternate methods of measuring soil moisture for watershed management purposes, we are experimenting with Nuclear-Chicago's Model 2800 d/M gauge and the P19 neutron moisture probe. Initial tests are encouraging--with relatively rock-free profiles and carefully placed access tubes, we are showing significant differences in moisture content (Pv) over periods as short as two days. With two months of use, the instrument has not developed any difficulties. Moisture measurements agree well with initial tests against gravimetric methods (no attempt has been made to calibrate the gauge against these relatively crude gravimetric values). We hope to have more to offer on this next summer.

Solar Radiation

The results presented by Vicksburg in the last issue were very interesting; although it might have been expected that evapotranspiration would be correlated to soil temperature, it is news to find it best correlated with this factor. We wonder if this remains true under forest canopy, or if measurements of soil temperature in the open would reflect water use by adjacent forest cover.

Vicksburg's results on soil moisture and bulk density variation point out some interesting differences from Coweeta's data. The standard deviation of bulk density at Coweeta is on the average twice as great, and there is a much clearer increase in bulk density with depth in our forest soils. Krumbach's data on sample numbers required to establish inches of moisture are apparently based on undisturbed samples, from which both bulk density and soil moisture in percent by weight are derived. This type of sampling is difficult to use where disturbance of the plot is of paramount importance. We have not made any study of the maximum allowable distance between samples, although this very much needed; because of the frequent changes in slope, aspect and elevation, we suspect that distance between samples would be a critical factor with us.

Since we are really sampling for different purposes, it is a little difficult to compare the methods we have described here with those being developed at Vicksburg. We will be interested in the reaction to these techniques, particularly as to whether anyone else can find use for them.

UNION RESEARCH CENTER

Soil Moisture Studies (FS-1-w1-6-SE)

Second year results of the study of effects of thinning Piedmont stands on soil moisture are partially analyzed. Soil moisture was sampled by gravimetric methods periodically throughout the growing season.

Preliminary analysis of current data indicates that evapotranspiration during the 1958 growing season exceeded that of the 1957 season and this is attributed to (1) more complete recharge of soils prior to the growing season and (2) to much more rainfall during the growing season of 1958. The moisture content of the soil was maintained at a high level through July of the current season and strong moisture stresses did not begin until August.

The following tabulation shows the evapotranspiration rates of the two years studied and illustrates the relation of basal area to evapotranspiration.

Basal Area per Acre (in square feet)	Average Daily Evapotranspiration by Depths (in inches)			
	0 - 4 feet		0 - 8 feet	
	1957	1958	1957	1958
150	.147	.160	.172	.196
75	.140	.148	.146	.172
45	.121	.156	.133	.166

Short Cuts in Soil Sampling

The above plots were utilized in a study of sampling techniques. From data collected during 1957, the optimum number of bulk density and percent moisture samples was determined for specified confidence levels. Analysis of bulk density data indicates that there is no significant difference in bulk density in the B-horizon or in the transition zone between B and C-horizons, regardless of depth from surface. This provides a time saver when converting percent moisture by weight into inches of water, since one factor can be used for the entire 8-foot depth of soil.

Also, average bulk density and percent by weight values can be applied to the entire depth of soil studied. Inches of water contained in the 4-foot profile was computed by 6-inch depths using the bulk density and percent moisture of each 6-inch depth. Then water was computed for one sample which was 48 inches in depth by using average bulk density and percent moisture. The difference between the two methods averages only 0.04 inch. Considering the accuracy of gravimetric sampling this difference is insignificant.

Thus, where trends in moisture for an entire profile are the study objectives, additional accuracy is not achieved by separating samples into arbitrary depths, and considerable laboratory and field work can be saved by using one composite sample. This simplification may not work for all soils, but it does offer time saving possibilities where it can be employed.

SEMI-ANNUAL REPORT
Division of Watershed Management Research
Southern Forest Experiment Station

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Results from Active Studies

Small Experimental Watersheds

At the Oxford, Mississippi, Research Center, three small experimental watersheds supporting 20-year-old loblolly pine plantations were put into operation on January 1, 1958. Other batteries of watersheds were already in operation on old fields and on depleted upland hardwood sites. Cumulative precipitation and surface runoff data from the three cover types for the first half of 1958 are shown in table 1.

Differences in runoff within cover types reflect variations in soils, particularly when the soil profiles are thoroughly wet. Old-field I, Hardwood III, and Pine III have fine-textured (silt-loam) loessial soils. Old-field I in addition has a shallow fragi-pan. The remaining watersheds have loessial ridges and upper slopes but grade into the coarser-textured (sandy-loam) Coastal Plain soils. Hardwood I is intermediate, being largely loess.

The outstanding comparison among cover types is the low amount of runoff from the 20-year-old loblolly pine plantations. Considering the heavy erosion which occurred on these areas before they were planted to pine, these preliminary data are almost startling.

Surface runoff for the six-month period immediately preceding the table (July-December 1957) ranged from 2.51 to 2.61 inches on the depleted upland hardwood condition, as compared to 6.76, 3.14, and 3.47 inches from Old-fields I, II, and III. The differences in storm runoff during this recharge period are believed to be due largely to the deeper, less eroded soils under the upland hardwoods. The data indicate, however, that once the soil moisture storage opportunity is satisfied there is little difference in the amount of storm runoff between the two cover types. While the amounts of surface runoff are similar (considering soil differences), the distribution is not, with considerably lower peak discharge rates from the hardwood type.

Herbaceous Cover Effect on Field Maximum

A beneficial influence of herbaceous cover has been indicated in studies at Vicksburg, Mississippi. In 1953, Colman fiber-glas units were installed in an open field to obtain a daily soil-moisture record for a study of the relationships of radiation to soil-moisture depletion. The field, formerly cultivated, supported grass and annual weeds, but had been mowed for some years. An area about 20 ft. by 40 ft. around the soil moisture units was left unmowed and undisturbed save for calibration sampling. By 1957 a heavy cover of Johnson grass, goldenrod and aster had developed and organic debris was present on the soil surface.

Table 1.--Cumulative precipitation and surface runoff on three cover types, Oxford, Mississippi

January - June 1958

Month	Precipitation	Surface runoff		
		I	II	III
	..... Inches			
Old Fields				
January	2.65	0.58	0.01	0.01
February	4.24	.64	.01	.01
March	8.81	1.98	.03	.03
April	19.33	7.61	1.83	1.96
May	22.26	8.14	1.88	1.98
June	30.77	10.00	2.54	2.62
Depleted Upland Hardwoods				
January	2.65	0.00	0.00	0.20
February	4.24	.00	.00	.20
March	8.81	.30	.00	.83
April	19.33	3.69	1.93	5.10
May	22.26	3.78	1.94	5.14
June	30.77	4.26	2.25	5.77
Loblolly Pine Plantations				
January	2.91	0.00	0.00	0.00
February	4.77	.00	.00	.00
March	8.96	.00	.00	.01
April	18.81	.01	.20	1.38
May	22.28	.01	.20	1.39
June	28.53	.01	.20	1.40

Examination of the soil-moisture curves for 1957 and 1958 indicated that field-maximum moisture content had increased from 2.59 in. to 2.95 in. in the 0-6 in. layer and from 2.35 in. to 2.45 in. in the 6-12 in. layer. The increase in field-maximum moisture content may result from activity of soil fauna or increase in root channels. Bulk density shows no appreciable change so the increased capacity may be the result of improvement in soil structure.

Mulching Affects Soil Temperatures

At Oxford, Mississippi, temperatures during summer were measured at the soil surface and one inch above the surface on Coastal Plain parent material and sands, with and without a two- to three-inch mulch of loose pine needles and wild hay. Continuous measurements were made using a Minneapolis Honeywell Brown 16-point, adjustable span recorder, and homemade cooper-constantan thermocouples. Some difficulty was experienced in obtaining absolute values due to a "drift" in the recorder.

On parent material the soil surface temperature under mulch was 20-25° F. cooler than the bare soil surface during midday. At night it was about 4° warmer.

The temperature one inch above the soil surface within the mulch at midday was 20-30° higher than the temperature one inch above a bare soil surface and remained higher day and night. Maximum bare soil surface temperatures in July approached temperatures lethal to plant protoplasm. Maximum temperatures of 130-150° within the mulch considerably exceeded the lethal range and indicate that the mulch functions as a heat trap. Further measurements at various times of the year are needed to fully evaluate the effects of mulch on tree regeneration, grass seeding, and other revegetation problems.

Soil Moisture in Arkansas Mountains

At no time during the 1958 growing season did soil moisture reach the permanent wilting point in the majority of the Mountain Province reports the Harrison, Arkansas, Research Center. This high soil moisture content resulted in extensive runoff from all plots in the hardwood to range conversion studies in north Arkansas —(described in the October 1957-March 1958 Semiannual Report). During dry years such areas reportedly yielded runoff only to very large, high intensity storms.

Another result of high soil moisture content was unusually good growth on pine stems with competing hardwood understory vegetation as well as where such vegetation was removed. The only increases in growth of cleared plots over the untreated occurred during the infrequent short intervals where soil moisture became low on the untreated plots. However, a late-season drought of 15 days almost completely stopped growth on the untreated plots (containing hardwoods and pine), while the treated plots with pine only continued to grow at an undiminished rate.

Variability in Soil Properties

An intensive sampling study of moisture content, Atterberg limits, texture, bulk density, organic matter, and 15-, 30-, and 60-cm. tension values was conducted on a highly variable loessial bottom soil, Falaya series, near Vicksburg, Miss. The 50 x 60 ft. plot was relatively level. Different spacing of samples, from 2.5 to 50 ft. apart, did not affect determination of the parameters studied.

The effect of microrelief on moisture-content distribution at a given time was studied on the same plot. The area contained a small draw 0.9 ft. deep on one side and a second draw 0.3 ft. to 0.6 ft. deep on the other. The difference between the highest and lowest points within the plot was 1.8 ft. Moisture contents were measured in the 6-12 in. layer (measured from the soil surface). Elapsed time for complete sampling with 120 observations was 1.5 hours.

The results under dry-soil conditions indicated that moisture content increased as "elevation" decreased. If a total mean moisture content for the entire plot (29.44 percent) is assumed to be correct, the mean moisture contents for the "wettest" and "driest" elevations deviate from this total mean by + 2.44 percent and - 4.52 percent, respectively. Such deviations could profoundly affect results in intensive soil studies. Furthermore, there was a highly significant difference in moisture content between the bottoms of the two draws. In intensive moisture studies on loessial bottom soils there is an apparent need to exercise great care in determining whether sampling is being carried out, for example, on a shallow filling area, on a shallow eroding area, or on the general level of topography.

Under wet-soil conditions mean moisture content for the entire plot was 36.08 percent by weight but there was no significant difference between the total mean and any "evaluation." Since this mean is almost the same as the 30-cm. tension value it probably represents as wet a condition as will be found in this soil.

Low Soil Moisture Depletion Rates in Puerto Rico

A soil-moisture study in Puerto Rico by the Vicksburg Center revealed that the average daily soil-moisture loss was about one half that of comparable sites in 9 areas located throughout the United States. Average soil moisture losses during the first 25 days after field maximum had been reached are shown in Table 2.

Table 2.--Average yearlong rate of moisture loss in Puerto Rico compared with summer moisture losses in the United States.

Area Location	No. of Sites	Average Daily Moisture Loss in Inches, 0-12" Depth
Puerto Rico	6	0.06
Vicksburg, Miss.	7	.12
Oxford, Miss.	3	.11
Alexandria, La.	2	.13
Nacogdoches, Texas	3	.10
Crossett, Ark.	5	.10
Poplar Bluff, Mo. and Grantsburg, Ill.	2	.12
Rhinelander, Wisc.	7	.10
Priest River, Idaho	4	.11
Fairbanks, Alaska	2	.10

Liquid Nitrogen Method of Soil Moisture Measurement

Laboratory studies by the Vicksburg Center of liquid-nitrogen probes in silt and sandy loam soils revealed that, in a moisture range from 2 to 175 percent by weight, such probes may be useful as all-purpose moisture-sampling devices. They also could be used to calibrate nuclear and electrical soil-moisture measuring devices which are employed over a wide range of moisture contents.

Comments

Freezing in Float Wells

Suggestion from J. L. Smith, Harrison, Arkansas, Research Center.

Stations using flumes such as the H-type sheet metal flume for measurement of intermittent flows from small watersheds commonly install float arresters to prevent the float, in the attached float well, from dropping below the zero point of the waterstage recorder chart. During summer months, water retained in the well after flow ceases is quickly evaporated. However, during winter months there is danger this water will freeze, bursting well seams or sticking the float so that it cannot move at the onset of water flow. The addition of a tiny "weep" hole near the base of the float well will permit draining of the well after flume water flow has ceased. The weep hole begins draining water as soon as it enters the well, preventing hole freezing. However, the outflow is so slight that the inflow if measurable, is enough to keep the well and flume flow at the same elevation. Under conditions of heavy siltation the weep hole should be placed about an inch above the base of the well.

Watershed Studies in Folded Strata

While large-scale watershed studies in the Ozarks, with their horizontally bedded strata, may be installed using the conventional weirs, such structures leave much to be desired in the Ouachitas. Due to the complex folding and fracturing of the Ouachitas, much of the infiltrated water passes downward to great depths. The net result is a cessation of water flow in the headwater areas of most small streams during the summer months. However, at points far enough downstream that the stream bed has cut into slowly permeable shale and slate beds, the streams begin a year-round flow. This flow appears to move underground through the valley fill until outcropping less permeable rock forces it to the surface. Unfortunately these places usually occur so far downstream that the valleys have become too wide and peak flows too widespread over the valley floor to permit water flow measurement with normal means.

Some of the pressing problems regarding the effect of cover manipulation upon water yield can only be answered from large scale watershed studies, and it becomes imperative that methods be developed which will permit measurement of flow change resulting from such manipulation, particularly the effect upon low flows and valley fill flows in dry weather. This valley fill flow appears to be extensive and of critical importance to municipal water supplies, fish population, and upland game.

A reasonably accurate estimate of quantities of valley fill flow might be secured through the use of ground water wells. A series of wells would be installed across the narrow, steep-sided valley draining a headwaters watershed, extending downward to a dense slate or shale layer. Core samples from these wells would be laboratory processed from determination of pore space content, and depth of water per unit of soil depth determined for the various valley fill layers. Thus knowing the depth of water in the ground water wells the real depth of water in the valley fill could be computed.

Rate of flow of the water through the valley fill might be determined by salting upper wells with radio-active isotopes and determination of travel time through periodic sampling of the lower wells.

With rate of flow, cross sectional valley area, and real water depth known, some measure of cover manipulation effects upon valley fill flow might be determinable.

Comments are urgently solicited.

Comparison of Soil Moisture Units

The Research Center at Nacogdoches, Texas, has three types of electrical resistance soil moisture units in operation; Colman-Fiberglas, Bouyoucos plaster-of paris, and Coshocton plaster-of paris units.

In using these units, several features have come up that deserve attention:

1. Colman units: Some units will not wet-up to maximum levels.

2. Coshocton units: The units have considerable variation in resistance at saturation. Also when reading with Colman Meter, there is considerable time-lag before stationary dial reading can be made.

3. Bouyoucos units: These are very uniform in resistance at saturation; also readings are made rapidly with Colman meter.

The following article was very helpful: Aitchison, G. D., Butler, P. F., and Gurr, C. G. Techniques associated with the use of gypsum block soil moisture meters. Australian Jour. of Applied Science 2(1): 56-75, 1951. The procedures for testing blocks prior to installation are essential if the Coshocton blocks are to be used.

Zahner at Crossett Research Center also reports that after one season, the odds are much in favor of the Bouyoucos units over Colman units for consistency of readings.

Portable Hydraulic Soil Core Sampler

In studies of the hydrologic cycle which include measurement of soil moisture, the Oxford Research Center finds it is necessary to convert soil moisture in percent by weight to a volumetric expression of the actual amount of water in the soil. Obtaining satisfactory bulk density values for conversion has long been a problem, particularly in dry or compacted soils at deep levels. Samplers driven or augered into the soil frequently compress the sample or damage soil structure. The Center is presently testing a simple portable core sampler operated by hydraulic pressure from the soil surface. Pressures well over a ton have been used to press a sampler head into dry subsoils four feet below the surface with bulk densities as high as 1.78.

Effect of Topography on Soil Moisture Regime

The Vicksburg Research Center is beginning a study on the influence of slope and aspect on the soil-moisture regime of the upper foot of soil. A second study will be concerned with the effect of land cover or lack of cover on soil-moisture depletion. Initially, both studies will review similar research completed or in progress elsewhere. The Center would be happy to receive copies of study plans, progress reports, and any miscellaneous memorabilia which might bear on these problems. The findings will be used to develop adjustment factors for the Vicksburg soil-moisture prediction method.